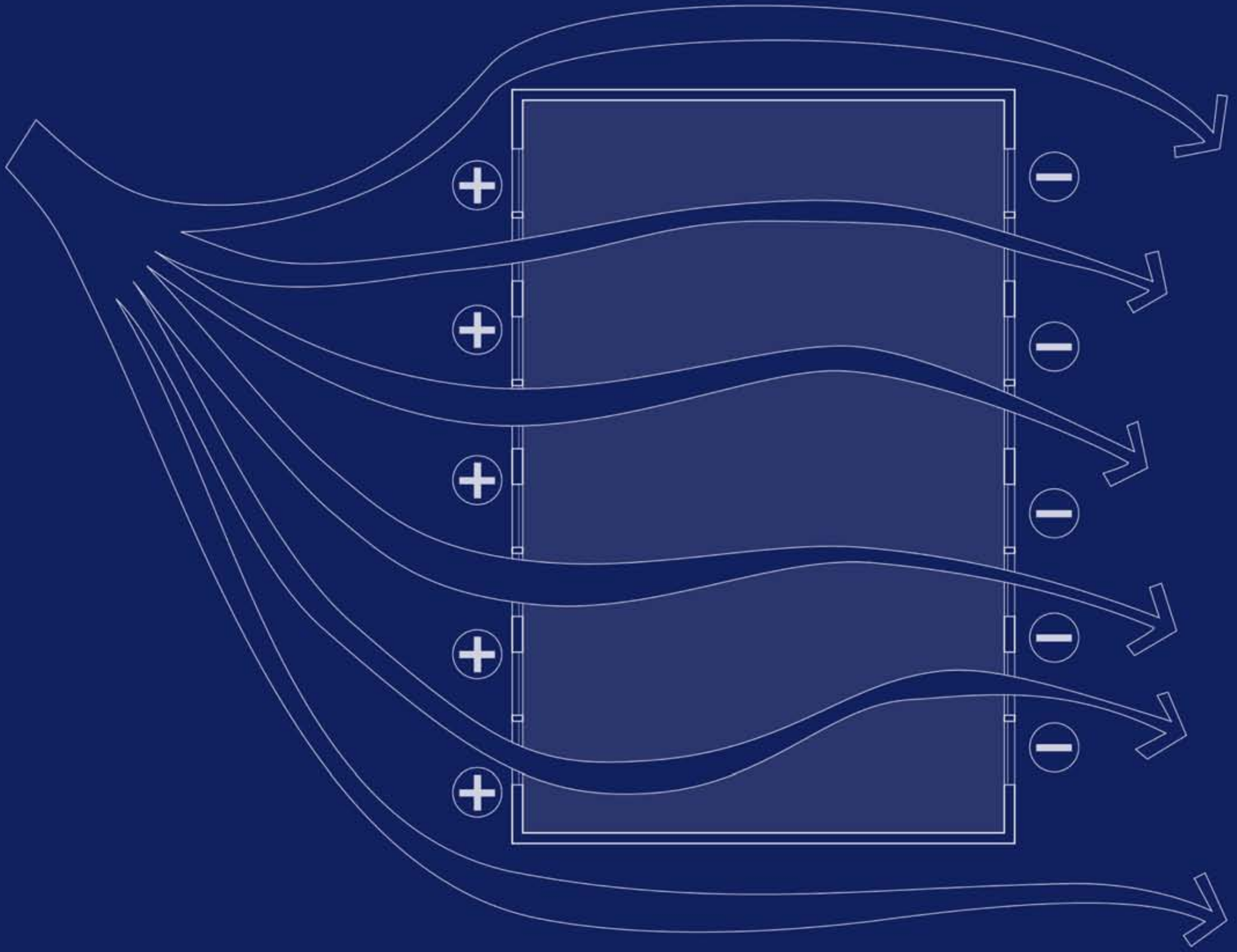
Fifth Edition



# THE ARCHITECT'S STUDIO COMPANION

## RULES OF THUMB FOR PRELIMINARY DESIGN

Edward Allen · Joseph Iano

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Edward Allen and Joseph Iano

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# HOW TO USE THIS BOOK

This book is your desktop technical advisor for the earliest stages of building design. It reduces complex engineering and building code information to simple formal and spatial approximations that are readily incorporated into design explorations. If you are not familiar with this book, below is a recommended pathway for completing the preliminary design of your building. For more detailed guidance on how to use the information in this book, see the full example beginning on page 473. Alternatively, information in this book may be accessed in any sequence that fits your particular needs or approach to designing buildings. To jump to any major topic, use the quick index that appears on the inside cover. From within any particular section, you may also follow the many cross references to related information in other parts. In the end, we hope this becomes your personalized handbook, an essential reference for your way of creating buildings.

**Step 1: Determine your building code and occupancy.** Starting on page 5, determine what model building code to use for your project and what Occupancy Classifications apply to the planned activities within your building. These pieces of information are your key to unlocking information throughout other sections of this book.

**Step 2: Find what types of construction are permitted for your project.** Based on the information determined in Step 1, consult the Height and Area Tables that begin on page 385 to determine what code-defined Construction Types are permitted for a building of your size and use.

**Step 3: Complete a preliminary structural design.** Review possible structural systems for your project, beginning on page 24, and consider approaches to the overall configuration of such systems, beginning on page 39. Once you have settled on a system for further study, you can complete a preliminary structural layout and assign approximate sizes to the system's major elements using the information beginning on page 55.

**Step 4: Consider using daylighting.** Use the information beginning on page 140 to study the potential benefits and formal implications of using daylight illumination in your project.

**Step 5: Plan for mechanical and electrical systems.** Use the information beginning on page 160 for large buildings, or on page 235 for small buildings, to consider heating and cooling systems that meet the needs of your project. Or, if you are particularly interested in passive heating and cooling systems, start on page 217. Once a viable system has been selected, use the information in the following sections to allocate spaces within your building for its HVAC, electrical, plumbing, and other systems.

**Step 6: Determine building code requirements for egress and accessibility.** Use the information that begins on page 265 to lay out the necessary components of your building's exiting system. If needed, incorporate provisions for accessibility as well.

**Step 7: Add accommodations for parking.** If provision for parking is a requirement of your project, use the information beginning on page 331 to evaluate both surface and structured parking options.

# SECTION
# 1

# DESIGNING WITH BUILDING CODES

# 1

# DESIGNING WITH BUILDING CODES

***This section will help you determine which model building code and occupancy classifications to apply to the project you are designing. You will need to know these facts to have full access to the information throughout this book.***

# BUILDING CODES AND ZONING ORDINANCES

A designer works under complex legal constraints that exert a powerful influence on the form a building may take. Local zoning ordinances control building uses, heights, areas, distances from property lines, and on-site parking capacities. Building codes enacted at the municipal, county, state, or provincial level regulate everything from building heights and areas to the types of interior finish materials that may be used. Further constraints are often imposed by local fire districts, by health and safety regulations pertaining to particular uses, and by national regulations governing equal access to public facilities and housing.

Zoning laws and use-specific codes are most often promulgated at the local level and do not lend themselves to simple generalization from one jurisdiction to the next. For this reason, this book does not attempt to address these requirements, and the designer should consult the regulations in effect for guidance in these areas. On the other hand, although building codes are also enacted at local levels, the vast majority of North American building codes are derived from just a few nationally recognized model codes. The use of model codes as the basis for the majority of local building codes results in sufficient standardization that these regulations can be simplified and generalized in a meaningful way. Thus, preliminary guidelines can be provided for incorporating building code requirements into your project.

This book provides building code information based on two model building codes: the International Code Council's *International Building Code* (*2009*) and the National Research Council of Canada, Canadian Commission on Building and Fire Codes' *National Building Code of Canada* (*2010*). These two model codes form the basis for the vast majority of building codes enacted by jurisdictions throughout the United States and Canada. This book condenses from these two model codes the provisions that have the most direct and important effects on building form: height and area limitations, beginning on page 363, and requirements for the design of egress systems, starting on page 261. Code requirements having to do with the detailed design of structural and mechanical components of buildings are reflected here indirectly through the preliminary sizing charts for structural elements (pages 55–135) and the rules of thumb for providing space for mechanical and electrical systems (pages 179–259).

To make use of the information provided in this book, start by selecting the model code appropriate to your project: for projects in the United States, the International Building Code, and for projects in Canada, the National Building Code of Canada. Next, consult the appropriate code-specific index that follows to ascertain the Occupancies for the building you are designing. These two pieces of information—model code and Occupancies—are the keys that will unlock code-related information throughout other sections of this book.

The building code information provided in the following pages is intended for preliminary purposes. The extent to which this information may accurately reflect the regulations with which any particular project must comply will differ from one locale to another: In some instances, a jurisdiction may adopt one of the model codes included in this book almost verbatim. In many cases, you will find that your project's locale has adopted one of these model codes, but with amendments or alterations to its requirements. And occasionally, you may encounter a jurisdiction that has written its own code or based its regulations on a model not addressed in this book. For these reasons, before becoming too deeply immersed in your design, be sure exactly which codes and regulations govern your project and verify that the information you use fully and accurately reflects the legal requirements that apply, whether that information comes from this book or other sources.

## WHICH BUILDING CODE TO CONSULT

If your project is in the United States, use the International Building Code, starting on this page, as the basis for determining preliminary code requirements for your project. If your project is in Canada, use the National Building Code of Canada, starting on page 13. For more information about model building codes and their applicability to your project, see page 5.

## OCCUPANCY CLASSIFICATION

Buildings, or portions of buildings, are classified by the activities for which they are used, termed *Occupancies*. These classifications reflect the relative life-safety hazards associated with the activities and occupant characteristics. In general, buildings intended for larger numbers of occupants, for public use, and for inherently hazardous activities are afforded greater levels of protection than those designed for smaller groups, private uses, and nonhazardous activities. Use the information on the following pages to determine which Occupancies most appropriately describe your project.

If your building contains multiple uses, determine the Occupancy classification for each part. Later in this book, you will find more information on how to apply the various code requirements to such mixed-occupancy facilities; if you would like to learn more about mixed-occupancy buildings right now, turn to page 368.

## GENERAL DESCRIPTION OF OCCUPANCIES

The following table describes each Occupancy according to the International Building Code.

| Occupancy | General Description |
|---|---|
| **A ASSEMBLY** | Assembly Occupancies include social, recreational, entertainment, and civic gatherings of 50 or more persons. Assembly Occupancy includes five subgroups:<br>A-1: This group includes theaters for the viewing of motion pictures and performing arts, usually with fixed seating.<br>A-2: This group includes food and drink establishments.<br>A-3: This group includes recreational, amusement, and worship uses not specifically covered by other Assembly subgroups, including, for example, galleries, churches, community halls, courtrooms, dance halls, indoor sports facilities without fixed seating, lecture halls, libraries, museums, passenger station waiting areas, and the like.<br>A-4: This group includes indoor sports facilities with spectator seating.<br>A-5: This group includes outdoor sports arenas.<br>Gathering spaces less than 750 sq ft (70 $m^2$) in area or accommodating fewer than 50 persons are treated as Group B, Business Occupancies, or, when located within other occupancies, as part of the surrounding Occupancy.<br>Assembly spaces located within Group E Educational facilities are treated as part of the Group E Occupancy. |
| **B BUSINESS** | Business Occupancies include office, professional, and service activities, and storage of related records and accounts. Business Occupancy also includes education facilities past the 12th grade, but does not include retail or wholesale sales, which are classified as Group M Mercantile. |

*(continued)*

# OCCUPANCIES: INTERNATIONAL BUILDING CODE

| Occupancy | General Description |
|---|---|
| **E EDUCATIONAL** | Educational Occupancies include schools for grades K through 12 and day care facilities for children older than 2½ years of age accommodating six or more children.<br>Auditoriums, gymnasiums, and other assembly areas within Group E facilities are treated as part of the Group E Occupancy. Educational facilities above the 12th grade are classified as Group B Business.<br>Educational rooms and auditoriums within religious facilities, accommodating not more than 99 persons, are considered part of that facility's overall classification, usually Group A-3 Assembly. If they accommodate 100 or more persons, such spaces must be classified separately as Group E.<br>An Educational Occupancy may also include day care for up to 100 children 2½ years and younger when all rooms housing such children are on the ground level and have exit doors leading directly to the exterior. |
| **F FACTORY INDUSTRIAL** | Factory Industrial Occupancies include manufacturing, fabricating, finishing, packaging, repairing, and other industrial processes, except those considered especially hazardous, classified as Group H Hazardous, or those classified as Group S Storage. Factory Occupancy has two subgroups:<br>F-1 Moderate-Hazard: This group includes manufacturing and industrial processes with moderate fire hazard, such as those involving aircraft, appliances, automobiles, machinery, electronics, plastics, printing, woodworking, and any others not classified as Group F-2.<br>F-2 Low-Hazard: This group includes manufacturing and industrial processes using nonflammable materials, such as those involving nonalcoholic beverages, brick and masonry, ceramics, glass, gypsum, ice, and metal fabrication.<br>Office and storage areas associated with factory facilities are classified as Group B and Group S Occupancies, respectively, unless they are small enough to be treated as accessory to the primary Factory Occupancy (see page 369 for Accessory Occupancies). |
| **H HIGH-HAZARD** | High-Hazard Occupancies include manufacturing, processing, and storage of materials with a high potential for health or fire hazard. Hazardous use classifications are specific and detailed about the amounts and types of explosive, flammable, corrosive, or toxic materials involved. If you are considering the design of such a facility, you should consult the building code from the very outset of your project to determine requirements. High-Hazard Occupancy has five subgroups:<br>H-1: This group includes facilities housing significant quantities of materials that are at risk of explosion or otherwise chemically highly unstable, for example, dynamite.<br>H-2: This group includes facilities housing significant quantities of materials that can act as accelerants in a fire, for example, flammable gasses or combustible dust.<br>H-3: This group includes facilities housing significant quantities of materials that readily support combustion or that otherwise present a physical hazard to occupants, such as combustible fibers, consumer fireworks, or oxidizing chemicals.<br>H-4: This group includes facilities housing significant quantities of materials that do not present a special fire hazard but are corrosive or highly toxic.<br>H-5: This group includes semiconductor fabrication plants and comparable research and development facilities that involve the use of significant quantities of materials specifically identified in the building code as hazardous production materials. |
| **I INSTITUTIONAL** | Institutional Occupancies include facilities where occupants cannot fully care for themselves, including residential care, health care, day care, and correctional facilities. Institutional Occupancies are divided into four subgroups:<br>I-1: This group includes 24-hour residential care facilities for 17 or more occupants (not including care staff), for example, group homes, assisted living facilities, convalescent homes, and alcohol and drug rehabilitation centers. Occupants must be capable of responding to an emergency without physical assistance from the facility staff. |

*(continued)*

| Occupancy | General Description |
|---|---|
| | I-2: This group includes 24-hour medical, psychiatric, and custodial care facilities in which occupants are not capable of self-preservation in an emergency, for example, hospitals, nursing homes, and child care facilities.<br>I-3: This group includes facilities with six or more occupants (not including staff) who are under restraint, detention, or security, for example, prisons, correctional centers, and reformatories.<br>I-4: This group includes nonmedical day care facilities for six or more occupants of any age (not including staff).<br>Offices, dining areas, gifts shops, and other such areas often associated with some Group I facilities should be classified as the appropriate A, B, or M Occupancies unless they are small enough to be treated as accessory to the primary I occupancy. (See page 369 for Accessory Occupancies.)<br>For more information on the classification of residential and day care facilities, see page 12. |
| **M MERCANTILE** | Mercantile Occupancies include the display and sale of retail and wholesale merchandise and the related stocking of such goods. |
| **R RESIDENTIAL** | Residential Occupancies include facilities where people live and sleep when not in a supervised setting that would not otherwise be classified as Institutional Occupancies. Residential Occupancies are divided into four subgroups:<br>R-1: This group includes hotels, motels, short-term boardinghouses, and other facilities where occupants are transient, typically with stays not exceeding 30 days.<br>R-2: This group includes apartment houses, nontransient boardinghouses, convents, dormitories, nontransient hotels and motels, time-share properties, and other facilities where occupants are primarily permanent.<br>R-3: This group includes residential facilities not classified as Group I Institutional or other R Occupancies, including one- and two-family residences, and care facilities (both 24-hour and day) for not more than five occupants of any age. Dormitories, fraternities and sororities, and other congregate living facilities where residents share kitchen, dining, and bath areas, with up to 16 permanent residents or 10 transient residents, may also be classified as Group R-3.<br>R-4: This group includes residential care or assisted living facilities for between 6 and 16 occupants above the age of 2½ years. Residents must be capable of self-preservation.<br>For more information on the classification of residential and day care facilities, see page 12.<br>Detached one- and two-family dwellings and townhouses, not more than three stories in height, most often are built to comply with the International Code Council's *International Residential Code*, a separate model code written specifically for these building types. Where the activities described above in Occupancies R-3 or R-4 are housed in such buildings, these buildings may in many cases be constructed to the requirements of this code. See also pages 430 and 432. |
| **S STORAGE** | This classification includes storage not classified as H Hazardous and is divided into two subgroups:<br>S-1 Moderate-Hazard: This group includes storage of books, paper, furniture, grain, lumber, tires, and other materials of moderate fire hazard, as well as motor vehicle repair facilities.<br>S-2 Low-Hazard: This group includes parking garages and buildings for the storage of noncombustible materials. |
| **U UTILITY AND MISCELLANEOUS** | This classification includes agricultural buildings and other structures not included in other occupancy classifications, such as aircraft hangars, carports, private garages, greenhouses, livestock shelters, retaining walls, sheds, stables, tanks, towers, and other miscellaneous uses. |

# OCCUPANCIES: INTERNATIONAL BUILDING CODE

## INDEX OF OCCUPANCIES

You may use the following detailed list of building uses to determine the Occupancy classifications for your project. If the specific use for your project is not listed, choose the most similar use based on comparisons of the number and density of occupants, nature of the activity, and any associated fire- or life-safety risks.

## WHERE DO I GO FROM HERE?

Once you have determined the building code Occupancy classifications for your project, you can use this information throughout the other sections of this book. If you are unsure of where to go next, see page ix, How to Use This Book, for suggestions on how to proceed.

| **Building Use** | **Occupancy** |
|---|---|
| Agricultural buildings, barns, livestock shelters | U |
| Aircraft hangars, accessory to one- or two-family residences | U |
| Aircraft hangars, storage and repair | S-1 |
| Aircraft manufacturing | F-1 |
| Airport traffic control towers | B |
| Alcohol and drug centers, 24-hour care | I-1; see also Institutional and Residential Care Occupancies, p. 12 |
| Amusement arcades | A-3 |
| Amusement park structures | A-5 |
| Animal hospitals, kennels, pounds | B |
| Apartment houses | R-2 |
| Art galleries | A-3 or B, depending on the number of occupants |
| Assisted living | I-1; see also Institutional and Residential Care Occupancies, p. 12 |
| Auditoriums | A-3 |
| Auditoriums, part of Group E Educational facilities | E |
| Banks | B |
| Banquet halls | A-2 |
| Barber and beauty shops | B |
| Barns | U |
| Bleachers, outdoors | A-5 |
| Boardinghouses, not transient | R-2 |
| Boardinghouses, transient | R-1 |
| Bowling alleys | A-3 |
| Business offices | B |
| Car washes | B |
| Care facilities, 24-hour | See Institutional and Residential Care Occupancies, p. 12 |
| Carports | U |
| Child care, 24-hour, 6 or more children 2½ years of age or less | I-2; see also Institutional and Residential Care Occupancies, p. 12 |
| Child care, day, 6 or more children 2½ years of age or less | I-4; see also Institutional and Residential Care Occupancies, p. 12 |
| Churches | See Places of worship |
| Civic administration | B |
| Clinics, outpatient | B |
| Community halls | A-3 |
| Concert halls | A-2 |
| Congregate living facilities combining individual sleeping units with shared dining, bathing, and recreation (such as dormitories, fraternities and sororities, and convents), 10 or fewer transient residents | R-3 |
| Congregate living, 11 or more transient residents | R-1 |
| Congregate living facilities, 16 or fewer permanent residents | R-3 |
| Congregate living facilities, 17 or more permanent residents | R-2 |

*(continued)*

# OCCUPANCIES: INTERNATIONAL BUILDING CODE

| Building Use | Occupancy |
|---|---|
| Convalescent facilities, 24-hour | I-1; see also Institutional and Residential Care Occupancies, p. 12 |
| Convents | See Congregate living facilities |
| Correctional centers | I-3 |
| Courtrooms | A-3 |
| Dance halls | A-3 |
| Day care, 5 or fewer occupants | R-3 |
| Day care, 6 or more occupants | I-4; see also Institutional and Residential Care Occupancies, p. 12 |
| Day surgery centers | B |
| Department stores | M |
| Detention centers | I-3 |
| Detoxification facilities, 24-hour | I-2; see also Institutional and Residential Care Occupancies, p. 12 |
| Doctors' offices | B |
| Drugstores | M |
| Dry boat storage | S-2 |
| Dry cleaners and laundries | B |
| Educational facilities, above the 12th grade | B |
| Educational facilities, K through 12 | E |
| Educational rooms in places of worship | Same occupancy as the main facility, usually A-3 |
| Electronic data processing | B |
| Exhibition halls | A-3 |
| Factories | F-1, F-2, or H, depending on the hazard |
| Fences, more than 6 ft (1.8 m) high | U |
| Fire and police stations | B |
| Fraternities | See Congregate living |
| Funeral parlors | A-3 |
| Grandstands, outdoors | A-5 |
| Greenhouses | U |
| Group homes | I-1; see also Institutional and Residential Care Occupancies, p. 12 |
| Gymnasiums | A-3 |
| Halfway houses, 17 or more persons | I-1; see also Institutional and Residential Care Occupancies, p. 12 |
| Hazardous materials processing and storage | H-1 through H-5; consult the code for more information |
| Homes, single- or two-family | See International Residential Code, p. 430 |
| Hospitals | I-2 |
| Hotels | R-1 |
| Jails | I-3 |
| Laboratories, testing and research | B |
| Lecture halls | A-3 |
| Libraries | A-3 |
| Markets | M |
| Medical care, 24-hour | I-2 |
| Monasteries | See Congregate living |
| Mosques | See Places of worship |
| Motels | R-1 |
| Motion picture theaters | A-1 |
| Motor vehicle repair | S-1 |
| Motor vehicle service stations | M |
| Motor vehicle showrooms | B |
| Museums | A-3 |
| Nightclubs | A-2 |
| Nursing homes | I-2 |
| Offices | B |
| Outpatient clinics | B |
| Parking garages, private | U |
| Parking garages, public | S-2 |
| Passenger station waiting areas | A-3 |
| Places of worship, including related public areas, gathering spaces, educational and child care areas | A-3 |
| Places of worship, business areas | B |
| Pool and billiard halls | A-3 |
| Post offices | B |
| Prisons | I-3 |
| Professional services | B |
| Radio and television stations with audience facilities | A-1 |
| Radio and television stations without audience facilities | B |

*(continued)*

# OCCUPANCIES: INTERNATIONAL BUILDING CODE

| Building Use | Occupancy |
|---|---|
| Reformatories | I-3 |
| Rehabilitation facilities | I-1; see also Institutional and Residential Care Occupancies, p. 12 |
| Religious facilities | See Places of worship |
| Residential care | See Institutional and Residential Care Occupancies, p. 12 |
| Restaurants | A-2 |
| Retail stores | M |
| Retaining walls | U |
| Salesrooms | M |
| Sheds | U |
| Skating rinks with spectator seating, indoor | A-4 |
| Sleep clinics | B |
| Sororities | See Congregate living |
| Sports arenas, indoor | A-4 |
| Stadiums, outdoors | A-5 |
| Storage | S-1, S-2, or H, depending on the hazard |
| Swimming pools, indoor, with spectator seating | A-4 |
| Swimming pools, indoor, without spectator seating | A-3 |
| Tanks | U |
| Taverns and bars | A-2 |
| Telephone exchanges | B |
| Tennis courts, indoors, with spectator seating | A-4 |
| Tennis courts, indoors, without spectator seating | A-3 |
| Theaters | A-1 |
| Tower structures, nonoccupied | U |
| Training centers, nonacademic | B |
| Wholesale stores | M |

## INSTITUTIONAL AND RESIDENTIAL CARE OCCUPANCIES

In the International Building Code, day care and residential care facilities are assigned to Occupancies based on the ages of the individuals under care, the number of individuals receiving care, the duration of the care, and the extent to which occupants can fend for themselves in the event of a building emergency. Use the following table to determine the most appropriate Occupancy classification for such uses. Other related classifications, not listed in the table, include the following:

- Day facilities for able-bodied adults who do not require personal care and are capable of responding to emergencies without assistance are classified as either Occupancy A-3 or B, depending on the number of occupants. This includes, for example, community centers, YMCAs, and other similar facilities.
- Doctors' offices, outpatient clinics, and similar facilities where patient stays do not exceed 24 hours are classified as Occupancy B.
- Facilities that provide medical care extending beyond a 24-hour stay and where residents require physical assistance in the case of a building emergency are classified as Occupancy I-2. This includes, for example, hospitals, nursing homes, detoxification facilities, and child care facilities with stays extending beyond 24 hours.

**DAY AND 24-HOUR NON-MEDICAL CARE OCCUPANCIES**

| **Age of Occupants** | **Day Care (less than 24-hour)** | | **24-Hour Care** | | |
|---|---|---|---|---|---|
| | 1–5 occupants | 6 or more occupants | 1–5 occupants | 6–16 occupants | 17 or more occupants |
| 2½ years or less | R-3 | I-4[a] | R-3 | I-2 | I-2 |
| Over 2½ years, not capable of self-preservation | R-3 | I-4[a] | R-3 | I-2 | I-2 |
| Over 2½ years and capable of self-preservation | R-3 | E for chldren up to the 12th grade<br>I-4 for adults[a] | R-3 | I-2 | I-1 |

The number of occupants includes only individuals receiving care, and excludes staff and care providers.

[a] Exceptions for I-4 Occupancies:

Day care occurring during worship activities within a religious facility may be classified with the primary Occupancy, usually A-3.

Up to 100 children 2½ years or less in age may receive day care in a Group E Occupancy when all such children are located in rooms on the ground floor having exit doors leading directly to the exterior.

Day care facilities for adults above the 12th grade and capable of responding to an emergency without assistance may also be classified as Group R-3 if the facility meets other code requirements for this Occupancy.

# OCCUPANCIES: NATIONAL BUILDING CODE OF CANADA

## WHICH BUILDING CODE TO CONSULT

If your project is in Canada, use the National Building Code of Canada, starting on this page, as the basis for determining preliminary code requirements for your project. If your project is in the United States, use the International Building Code, starting on page 6. For more information about model building codes and their applicability to your project, see page 5.

## OCCUPANCY CLASSIFICATION

Buildings, or portions of buildings, are classified by the activities for which they are used, termed *Occupancies*. These classifications reflect the relative life-safety hazard associated with the activities and occupant characteristics. In general, buildings intended for larger numbers of occupants, for public use, and for inherently hazardous activities are afforded greater levels of protection than those designed for smaller groups, private uses, and nonhazardous activities. Use the information on the following pages to determine which occupancies most appropriately describe your project.

If your building contains multiple uses, determine the Occupancy classification for each part. Later in this book, you will find more information on how to apply the various code requirements to such mixed-use facilities; if you would like to learn more about mixed-use buildings right now, turn to page 368.

## GENERAL DESCRIPTION OF OCCUPANCIES

The following table describes each Occupancy according to the National Building Code of Canada.

| Occupancy | General Description |
|---|---|
| **A ASSEMBLY** | Assembly Occupancy includes social, recreational, and civic gatherings and includes four subdivisions:<br>A-1: This division includes facilities for the public production and viewing of the performing arts, such as motion picture theaters, performing arts halls and theaters, and broadcast studios with viewing audiences.<br>A-2: This division includes a broad range of assembly-type uses not specifically falling under other Assembly subdivisions, for example, auditoriums, churches, community halls, courtrooms, dance halls, gymnasiums, lecture halls, libraries, museums, passenger stations and depots, nonresidential schools and colleges, and other public gathering facilities.<br>A-3: This division includes indoor arena-type facilities, such as swimming pools (with or without spectator seating), arenas, and rinks.<br>A-4: This division includes open-air assembly facilities such as outdoor sports stadiums, amusement park structures, and other facilities with outdoor bleachers or grandstands. |
| **B CARE, TREATMENT, OR DETENTION** | Care, Treatment, or Detention Occupancy includes facilities where occupants cannot fully care for themselves and includes three subdivisions:<br>B-1: This division includes detention occupancies in which occupants are under restraint or incapable of self-preservation due to security measures, such as prisons and jails, as well as psychiatric hospitals, reformatories, and other care facilities with detention quarters.<br>B-2: This division includes medical or health-related treatment Occupancies that do not include detention, such as hospitals, infirmaries, and psychiatric hospitals, as well as convalescent homes, hospices, nursing homes, respite centers, and other similar facilities when medical treatment is provided.<br>B-3: This division includes facilities providing cognitive, behavioral, or physical care, without medical treatment or detention, such as assisted living facilities, children's custodial homes, convalescent homes, group homes, nursing homes, reformatories, and respite centers. |

*(continued)*

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| Occupancy | General Description |
|---|---|
| **C RESIDENTIAL** | Residential Occupancy includes all kinds of residential facilities not classified as Care or Detention, such as apartment houses, boardinghouses, residential colleges and schools, hotels, single-family houses, and the like. |
| **D BUSINESS AND PERSONAL SERVICES** | Business and Personal Services Occupancy includes office, professional, and service facilities, such as banks, beauty parlors, doctors' offices, business offices, police stations (without detention), and radio stations. This occupancy does not include retail or wholesale sales, which are classified as Occupancy E. |
| **E MERCANTILE** | Mercantile Occupancies include the display and sale of retail and wholesale merchandise and the related stocking of such goods. |
| **F INDUSTRIAL** | Industrial Occupancies include manufacturing and industrial facilities and includes three subdivisions:<br>F-1: This division includes high-hazard manufacturing processes, such as those involving highly flammable or hazardous substances.<br>F-2: This division includes medium-hazard manufacturing processes and materials.<br>F-3: This division includes low-hazard manufacturing processes and materials. |

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## INDEX OF OCCUPANCIES

You may also use the following index of uses to determine the Occupancy classifications for your project. If the specific use for your project is not listed, choose the most similar use based on comparisons of the number and density of occupants, the nature of the activity, and any associated fire- or life-safety risks.

## WHERE DO I GO FROM HERE?

Once you have determined the building code Occupancy classifications for your project, you can use this information throughout the other sections of this book. If you are unsure of where to go next, see page ix, How to Use This Book, for suggestions on how to proceed.

| Building Use | Occupancy |
|---|---|
| Aircraft hangars | F-2 |
| Aircraft hangars (light-aircraft, storage only) | F-3 |
| Amusement park structures | A-4 |
| Apartments | C |
| Appliance rental and service establishments, small | D |
| Arenas, indoor, including use for occasional trade shows or exhibitions | A-3 |
| Art galleries | A-2 |
| Assisted living facilities | B-3 |
| Auditoriums | A-2 |
| Banks | D |
| Barbershops | D |
| Beauty shops | D |
| Beverage establishments | A-2 |
| Bleachers, open-air | A-4 |
| Boardinghouses | C |
| Bowling alleys | A-2 |
| Box factories | F-2 |
| Candy manufacturing plants | F-2 |
| Care facilities, with medical treatment | B-2 |
| Care facilities, without medical treatment | B-3 |
| Cereal mills | F-1 |
| Chemical plants | F-1 |
| Children's custodial homes | B-3 |
| Children's custodial homes, with not more than 10 ambulatory occupants living as a single housekeeping unit | C |
| Clubs, nonresidential | A-2 |
| Cold storage | F-2 |
| Colleges, nonresidential | A-2 |

| Building Use | Occupancy |
|---|---|
| Colleges, residential | C |
| Community halls | A-2 |
| Concert halls | A-1 |
| Convalescent centers, with medical treatment | B-2 |
| Convalescent centers, with not more than 10 ambulatory occupants living as a single housekeeping unit | C |
| Convalescent centers, without medical treatment | B-3 |
| Convents | C |
| Courtrooms | A-2 |
| Creameries | F-3 |
| Dance halls | A-2 |
| Dental offices | D |
| Department stores | E |
| Distilleries | F-1 |
| Dormitories | C |
| Dry cleaning establishments, not using flammable or explosive solvents or cleaners | F-2 |
| Dry cleaning establishments, self-service | D |
| Dry cleaning plants, other | F-1 |
| Electrical stations | F-2 |
| Exhibition halls, mercantile | E |
| Exhibition halls, other than mercantile | A-2 |
| Factories | F-1, F-2, or F-3, depending on the hazard |
| Farm buildings | Must conform to the National Farm Building Code of Canada, which is not included in this book |

*(continued)*

# OCCUPANCIES: NATIONAL BUILDING CODE OF CANADA

| Building Use | Occupancy |
|---|---|
| Feed mills | F-1 |
| Flour mills | F-1 |
| Freight depots | F-2 |
| Garages, repair | F-2 |
| Grain elevators | F-1 |
| Grandstands, open-air | A-4 |
| Group homes | B-3 |
| Gymnasiums | A-2 |
| Hairdressing shops | D |
| Helicopter rooftop landing areas | F-2 |
| Hospices, with medical treatment | B-2 |
| Hospices, without medical treatment | B-3 |
| Hospitals | B-2 |
| Hotels | C |
| Houses | C |
| Industrial salesrooms | F-1, F-2, or F-3, depending on the hazard |
| Industrial sample display rooms | F-3 |
| Infirmaries | B-2 |
| Jails | B-1 |
| Laboratories | F-1, F-2, or F-3, depending on the hazard |
| Lacquer factories | F-1 |
| Laundries, except self-service | F-2 |
| Laundries, self-service | D |
| Lecture halls | A-2 |
| Libraries | A-2 |
| Lodging houses | C |
| Markets | E |
| Mattress factories | F-1 or F-2, depending on the hazard |
| Medical offices | D |
| Monasteries | C |
| Motels | C |
| Motion picture theaters | A-1 |
| Museums | A-2 |
| Nursing homes, with medical treatment | B-2 |
| Nursing homes, without medical treatment | B-3 |
| Opera houses | A-1 |
| Paint, varnish factories | F-1 |
| Paper recycling plants | F-1 |
| Parking garages, enclosed or open | F-3 |
| Passenger stations, depots | A-2 |

| Building Use | Occupancy |
|---|---|
| Penitentiaries | B-1 |
| Places of worship | A-2 |
| Planing mills | F-2 |
| Police stations, not more than one story in height and 600 m$^2$ (6460 ft$^2$) in building area | B-2 |
| Police stations, with detention quarters | B-1 |
| Police stations, without detention facilities | D |
| Power plants | F-3 |
| Printing plants | F-2 |
| Prisons | B-1 |
| Psychiatric hospitals, with detention quarters | B-1 |
| Psychiatric hospitals, with medical treatment | B-2 |
| Radio stations | D |
| Recreational piers | A-2 |
| Reformatories, with detention quarters | B-1 |
| Reformatories, without medical treatment | B-3 |
| Rehabilitation centers, with medical treatment | B-2 |
| Rehabilitation centers, without medical treatment | B-3 |
| Respite centers, with medical treatment | B-2 |
| Respite centers, without medical treatment | B-3 |
| Restaurants | A-2 |
| Reviewing stands, open-air | A-4 |
| Rinks, indoor | A-3 |
| Rubber processing plants | F-1 |
| Schools, nonresidential | A-2 |
| Schools, residential | C |
| Service stations | F-2 |
| Shops | E |
| Spray painting operations | F-1 |
| Stadiums, open-air | A-4 |
| Storage, baled combustible fibers | F-2 |
| Storage, bulk, flammable liquids | F-1 |
| Storage, bulk, hazardous chemicals | F-1 |
| Storage, other | F-1, F-2, or F-3, depending on the hazard |
| Stores | E |

*(continued)*

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| Building Use | Occupancy |
|---|---|
| Supermarkets | E |
| Swimming pools, indoor, with or without spectator seating | A-3 |
| Television studios, admitting a viewing audience | A-1 |
| Television studios, with a viewing audience | D |
| Television studios, without a viewing audience | F-2 |
| Theaters, performance | A-1 |
| Tool rental and service establishments, small | D |
| Warehouses | F-1, F-2, or F-3, depending on the hazard |
| Wholesale rooms | F-2 |
| Woodworking shops | F-2 |
| Workshops | F-2 or F-3, depending on the hazard |

## SECTION

## 2

# DESIGNING THE STRUCTURE

# 1

# SELECTING THE STRUCTURAL SYSTEM

***This section will help you select a structural system for the preliminary design of your building.***

# BUILDING CODE CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS

When choosing a structural system for a building, you must first determine the range of systems permitted by the building code in effect for your project. Each of the model codes requires you to do this by first determining the Occupancy classifications for a building. Then you must consult numerous detailed provisions of the code that prescribe the maximum height and floor area to which the building may be built, based on its Occupancy and a range of code-defined Construction Types. To streamline this process, simplified tables of area and height limitations for each model code are provided in this book. To use these tables, proceed as follows:

- If you have not already done so, first determine which model code applies to your building and the Occupancy classifications into which it falls (pages 6–17).
- Refer to the Height and Areas Tables, beginning on page 385, and locate the one or more tables that apply to your building.
- Based on the size of the building required for your project, read from the Height and Area Tables the allowable Construction Types.
- To learn more about each acceptable Construction Type, see pages 380–384.

Knowing what Construction Types are permitted for your project will help you in making preliminary selections of structural systems on the pages that follow in this section.

# DESIGN CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS

| | |
|---|---|
| *If you wish to create a building with a highly irregular form:* | Choose systems with simple floor and roof framing that are fabricated mostly on-site, such as:<br>Sitecast concrete using any slab system without beams or ribs (pages 107–111, 114–115, 118–121)<br>Light gauge steel framing (pages 91–95)<br>Platform frame (pages 57–66)<br>Masonry construction with either concrete slab or wood light floor framing (pages 79–90) |
| *If you wish to leave the structure exposed while retaining a high fire-resistance rating:* | Choose structural systems that are inherently resistant to fire and heat, including:<br>All concrete systems (although ribbed systems may require added thickness in the ribs or slab, or applied fireproofing) (pages 107–135)<br>Heavy timber frame (pages 66–77)<br>Mill construction (pages 57, 79, 66–77)<br>Structural steel is highly susceptible to loss of strength in a fire and usually must be protected with a fire-resistive finishing system. For further information on the fire resistance of various structural systems and uses for which they are permitted, see pages 376–384. |
| *If you wish to allow column placements that deviate from a regular grid:* | Use systems that do not include beams or joists in the floor and roof structure, such as:<br>Sitecast concrete two-way flat plate or flat slab (pages 118–121)<br>Metal space frame |
| *If you wish to minimize floor thickness to reduce total building height or to reduce floor spandrel depth on the building facade:* | The thinnest floor systems are concrete slabs without ribs, preferably prestressed, such as:<br>Sitecast concrete two-way flat plate or flat slab, especially when posttensioned (pages 118–121)<br>Precast prestressed hollow core or solid slab (pages 132–133)<br>Posttensioned one-way solid slab (pages 114–115) |
| *If you wish to minimize the area occupied by columns or bearing walls:* | Consider long-span structural systems, such as:<br>Heavy wood trusses (pages 74–75)<br>Glue-laminated wood beams (pages 72–73)<br>Glue-laminated wood arches (pages 76–77)<br>Steel frame (pages 96–103)<br>Open-web steel joists (page 104)<br>Single-story rigid steel frame (page 105)<br>Steel trusses (page 106)<br>Sitecast concrete one-way joist or waffle slab, particularly when posttensioned (pages 116–117, 122–123)<br>Precast concrete single or double tees (pages 134–135)<br>You may also wish to consider other long-span systems, such as specially fabricated steel beams, suspended systems, arches, vaults, and shells. |

# DESIGN CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS

| | |
|---|---|
| *If you wish to allow for changes to the building over time:* | Consider short-span one-way systems that permit easy structural modification, such as:<br>Light gauge or conventional steel frame (pages 91–104)<br>Any wood system (pages 57–77)<br>Sitecast concrete one-way solid slab or one-way joist construction, excluding posttensioned (pages 114–117)<br>Precast concrete solid or hollow core slab (pages 132–133) |
| *If you wish to permit construction under adverse weather conditions:* | Select a system that does not depend on on-site chemical processes (such as the curing of concrete or mortar) and that can be erected quickly, such as:<br>Any steel system (pages 91–106)<br>Any wood system (pages 57–77)<br>Precast concrete systems, particularly those that minimize the use of sitecast concrete toppings and grouting (pages 125–135) |
| *If you wish to minimize site disturbance during construction:* | Choose column and beam systems supported on point footings, thereby minimizing excavation, such as:<br>Heavy timber frame (pages 67–71)<br>Steel frame (pages 96–103)<br>Choose long-span systems that minimize bearing elements, such as:<br>Heavy wood trusses (pages 74–75)<br>Glue-laminated wood beams (pages 72–73)<br>Glue-laminated wood arches (pages 76–77)<br>Open-web steel joists (page 104)<br>Steel trusses (page 106)<br>Choose systems that rely on a high degree of off-site prefabrication to minimize construction activities on site, such as:<br>Single-story rigid frames (page 105)<br>Any precast concrete system (pages 125–135) |
| *If you wish to minimize off-site fabrication time:* | Consider systems in which the building is constructed on-site from easily formed, relatively unprocessed materials, such as:<br>Any sitecast concrete system (pages 107–123)<br>Light gauge steel framing (pages 92–95)<br>Platform frame (pages 58–65)<br>Any masonry system (pages 79–90) |
| *If you wish to minimize on-site erection time:* | Consider systems using highly preprocessed, prefabricated, or modular components, such as:<br>Single-story rigid steel frame (page 105)<br>Steel frame, particularly with hinge connections (pages 96–104)<br>Any precast concrete system (pages 125–135)<br>Heavy timber frame (pages 66–77) |

# DESIGN CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS

| | |
|---|---|
| *If you wish to minimize construction time for a one- or two-story building:* | Consider systems that are lightweight and easy to form, or prefabricated and easy to assemble, such as:<br>Any steel system (pages 91–106)<br>Heavy timber frame (pages 66–77)<br>Platform frame (pages 58–65) |
| *If you wish to minimize construction time for a 4- to 20-story building:* | Choose from the following systems:<br>Precast concrete (pages 125–135)<br>Steel frame (pages 96–104)<br>Once the structural components for either of the above systems are prefabricated, on-site erection proceeds quickly.<br>Any sitecast concrete system (pages 107–123)<br>The absence of lead time for the prefabrication of components in sitecast concrete systems allows construction of the building to begin on-site at the earliest time. |
| *If you wish to minimize construction time for a building 30 stories or more in height:* | Choose a system that is strong, lightweight, prefabricated, and easy to assemble:<br>Steel frame (pages 96–103)<br>Systems of precast and sitecast concrete are economical alternatives to steel frame construction in some regions. |
| *If you wish to minimize the need for diagonal bracing or shear walls:* | Choose a system that is capable of economically forming rigid joints, such as:<br>Any sitecast concrete system, particularly those with beams or deepened slabs around the columns (pages 107–123)<br>Steel frame with welded rigid connections (pages 96–103)<br>Single-story rigid steel frame (page 105)<br>When depending on a rigid frame for lateral stiffness, the sizes of the framing members often must be increased to resist the added bending stresses produced in such systems. |
| *If you wish to minimize the dead load on the building foundation:* | Consider lightweight or short-span systems, such as:<br>Any steel system (pages 91–105)<br>Any wood system (pages 57–71) |
| *If you wish to minimize structural distress due to unstable foundation conditions:* | Frame systems without rigid joints are recommended, such as:<br>Steel frame, with bolted connections (pages 96–104)<br>Heavy timber frame (pages 66–77)<br>Precast concrete systems (pages 125–135)<br>Platform framing (pages 58–63)<br>Welded steel frames, masonry bearing walls, and sitecast concrete frames are particularly to be avoided. |

| | |
|---|---|
| *If you wish to minimize the number of separate trades and contracts required to complete the building:* | Consider systems that incorporate many of the functions of a complete wall system in one operation, such as:<br>Masonry construction, including Mill or Ordinary construction (pages 77–90)<br>Precast concrete loadbearing wall panel systems (pages 128–129) |
| *If you wish to provide concealed spaces within the structure itself for ducts, pipes, wires, and other building mechanical systems:* | Consider systems that naturally provide convenient hollow spaces, such as:<br>Light truss and open-web joist systems (pages 64–65, 104)<br>Light gauge steel framing (pages 92–95)<br>Platform frame (pages 58–65)<br>Light gauge steel framing and platform frame construction are often applied as finish or infill systems in combination with other types of building structures to provide such spaces. For more information on the integration of building services and the structural system, see pages 190–192, 205–208, and 257. |

# DESIGN CRITERIA: SUMMARY CHART

| | **WOOD AND MASONRY** | | | | **STEEL** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Pages 58–65** | **Pages 66–77** | **Pages 79–90** | **Pages 79–90** | **Pages 92–95** | **Page 105** | **Pages 96–104** | **Pages 96–104** |
| **GIVE SPECIAL CONSIDERATION TO THE SYSTEMS INDICATED IF YOU WISH TO:** | **Platform Frame** | **Heavy Timber Frame** | **Ordinary Construction** | **Mill Construction** | **Lightweight Steel Framing** | **Single-Story Rigid Steel Frame** | **Steel Frame—Hinged Connections** | **Steel Frame—Rigid Connections** |
| Create a highly irregular building form | ● | | ● | | ● | | | |
| Expose the structure while retaining a high fire-resistance rating | | ● | | ● | | | | |
| Allow column placements that deviate from a regular grid | | | | | | | | |
| Minimize floor thickness | | | | | | | | |
| Minimize the area occupied by columns or bearing walls | | | | | | ● | ● | ● |
| Allow for changes in the building over time | ● | ● | ● | ● | ● | | ● | ● |
| Permit construction under adverse weather conditions | ● | ● | | | ● | ● | ● | ● |
| Minimize site disturbance | | ● | | | | ● | ● | ● |
| Minimize off-site fabrication time | ● | | ● | ● | ● | | | |
| Minimize on-site erection time | | ● | | | | ● | ● | ● |
| Minimize construction time for a one- or two-story building | ● | ● | | | ● | ● | ● | ● |
| Minimize construction time for a 4- to 20-story building | | | | | | | ● | ● |
| Minimize construction time for a building 30 stories or more in height | | | | | | | ● | ● |
| Avoid the need for diagonal bracing or shear walls | | | | | | ● | | ● |
| Minimize the dead load on a foundation | ● | ● | | | ● | ● | ● | ● |
| Minimize structural distress due to unstable foundation conditions | ● | ● | | | | | ● | |
| Minimize the number of separate trades needed to complete a building | | | ● | ● | | | | |
| Provide concealed spaces for ducts, pipes, etc. | ● | | ● | | ● | | | |

# DESIGN CRITERIA: SUMMARY CHART

| SITECAST CONCRETE | | | | | | | | | | PRECAST CONCRETE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pages 114–115 | Pages 114–115 | Pages 116–117 | Pages 116–117 | Page 118–119 | Pages 118–119 | Pages 120–121 | Pages 120–121 | Pages 122–123 | Pages 122–123 | Pages 132–133 | Pages 132–133 | Pages 134–135 | Pages 134–135 |
| **One-Way Solid Slab** | **Posttensioned One-Way Solid Slab** | **One-Way Joist** | **Posttensioned One-Way Joist** | **Two-Way Flat Plate** | **Posttensioned Two-Way Flat Plate** | **Two-Way Flat Slab** | **Posttensioned Two-Way Flat Slab** | **Waffle Slab** | **Posttensioned Waffle Slab** | **Solid Slab** | **Hollow Core Slab** | **Double Tee** | **Single Tee** |
| ● | ● | | | ● | ● | ● | ● | | | | | | |
| ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | | | | ● | ● | ● | ● | | | | | | |
| | ● | | | ● | ● | ● | ● | | | ● | ● | | |
| | | ● | ● | | | | | ● | ● | | | ● | ● |
| ● | | ● | | | | | | | | ● | ● | | |
| | | | | | | | | | | ● | ● | ● | ● |
| | | | | | | | | | | ● | ● | ● | ● |
| ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | | |
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| ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
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| ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | | |
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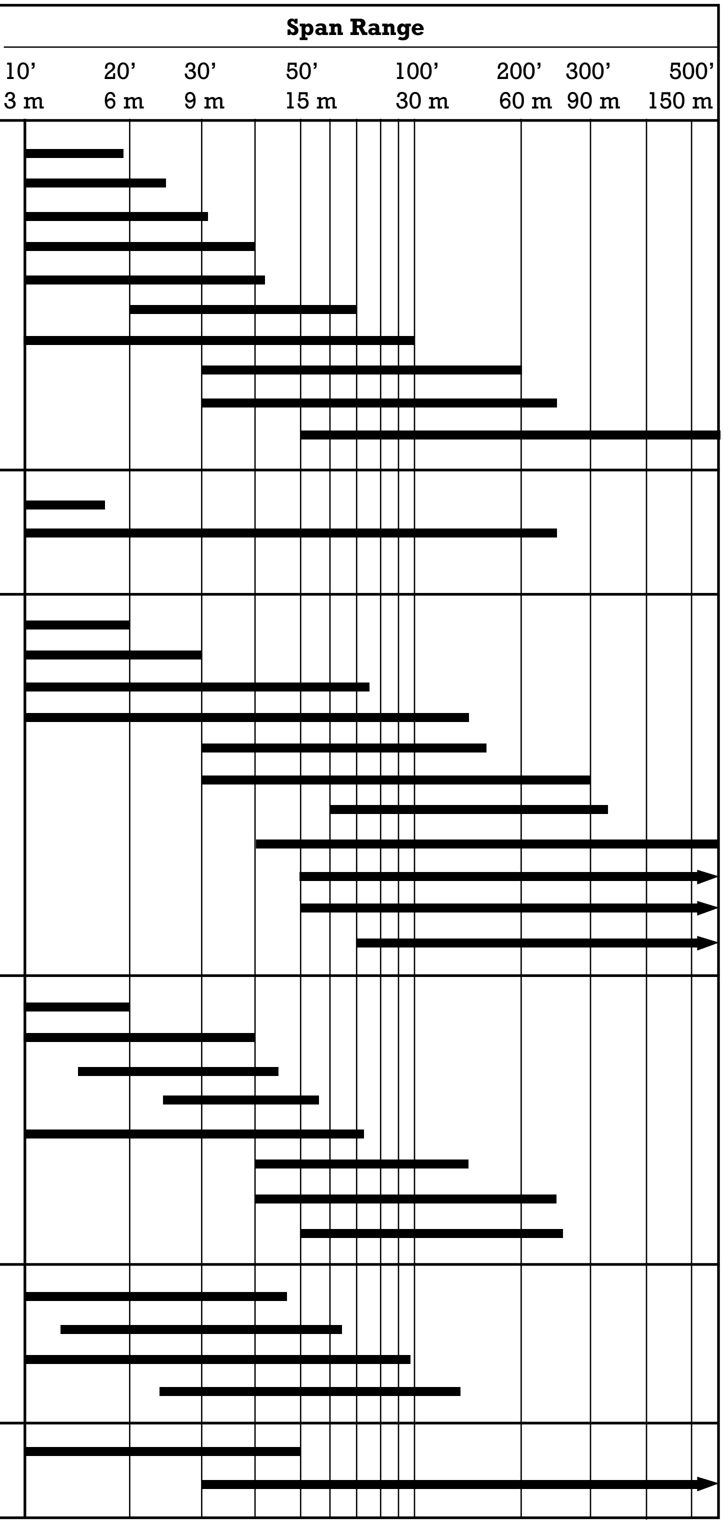
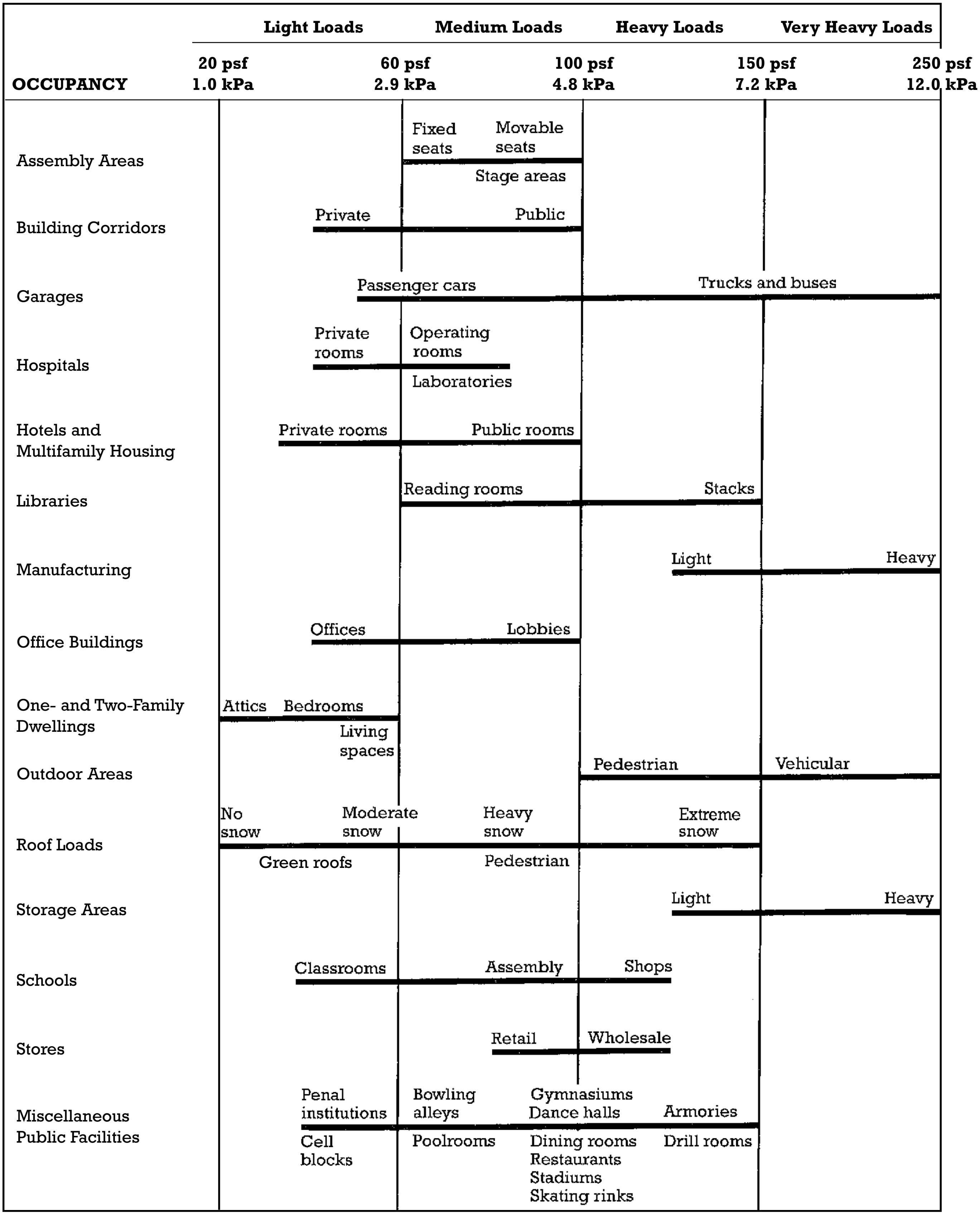
# PRACTICAL SPAN RANGES FOR STRUCTURAL SYSTEMS

This chart gives common practical span ranges for various structural systems. Spans beyond the ranges indicated may be possible in some circumstances. Page references are included where a system indicated is covered in greater detail elsewhere in this book.

| STRUCTURAL SYSTEM | | Pages |
|---|---|---|
| **WOOD** | Joists | 60–61 |
| | Decking | 68–69 |
| | Solid Beams | 70–71 |
| | Rafter Pairs | 62–63 |
| | Light Floor Trusses | 64–65 |
| | Light Roof Trusses | 64–65 |
| | Glue-Laminated Beams | 72–73 |
| | Heavy Trusses | 74–75 |
| | Glue-Laminated Arches | 76–77 |
| | Domes | |
| **BRICK & CONCRETE MASONRY** | Lintels | 84, 90 |
| | Arches | 85 |
| **STEEL** | Corrugated Decking | 100–101 |
| | Lightweight Steel Joists | 94–95 |
| | Beams | 102–103 |
| | Open-Web Joists | 104 |
| | Single-Story Rigid Frames | 105 |
| | Heavy Trusses | 106 |
| | Arches and Vaults | |
| | Space Frame | |
| | Domes | |
| | Cable-Stayed | |
| | Suspension | |
| **SITECAST CONCRETE** | One-Way Slabs | 114–115 |
| | Two-Way Slabs | 118–121 |
| | One-Way Joists | 116–117 |
| | Waffle Slab | 122–123 |
| | Beams | 112–113 |
| | Folded Plates and Shells | |
| | Domes | |
| | Arches | |
| **PRECAST CONCRETE** | Slabs | 132–133 |
| | Beams | 130–131 |
| | Double Tees | 134–135 |
| | Single Tees | 134–135 |
| **PNEUMATIC** | Air Inflated | |
| | Air Supported | |



## LIVE LOAD RANGES FOR BUILDING OCCUPANCIES



# LIVE LOAD RANGES FOR STRUCTURAL SYSTEMS

### LIVE LOAD RANGES FOR STRUCTURAL SYSTEMS

| STRUCTURAL SYSTEM | | Pages | Light Loads | Medium Loads | Heavy Loads | Very Heavy Loads |
|---|---|---|---|---|---|---|
| **WOOD** | Platform Frame | 58–65 | ━ | ━ | | |
| | Heavy Timber Frame | 66–77 | ━ | ━ | ━ | ━ |
| **MASONRY** | Ordinary Construction | 79–90 | ━ | ━ | | |
| | Mill Construction | 79–90 | | ━ | ━ | ━ |
| **STEEL** | Lightweight Steel Framing | 92–95 | ━ | ━ | | |
| | Single-Story Rigid Steel Frame | 105 | ━ | ━ | (Roof loads only) | |
| | Conventional Steel Frame | 96–104 | | ━ | ━ | ━ |
| **SITECAST CONCRETE** | One-Way Solid Slab | 114–115 | ━ | ━ | ━ | |
| | One-Way Beam and Slab | 114–115 | | | ━ | ━ |
| | One-Way Joists | 116–117 | | ━ | ━ | ━ |
| | Two-Way Flat Plate | 118–119 | ━ | ━ | | |
| | Two-Way Flat Slab | 120–121 | | ━ | ━ | ━ |
| | Waffle Slab | 122–123 | | ━ | ━ | ━ |
| | Two-Way Beam and Slab | 118–119 | | | ━ | ━ |
| **PRECAST CONCRETE** | Solid Slab | 132–133 | ━ | ━ | ━ | |
| | Hollow Core Slab | 132–133 | ━ | ━ | ━ | |
| | Double Tee | 134–135 | | ━ | ━ | ━ |
| | Single Tee | 134–135 | | ━ | ━ | ━ |

Use the charts on these two pages to identify appropriate structural systems based on loads generated by the activities planned within the building. Read the chart on the facing page first to determine the live load range associated with the expected building use. Once a load range has been determined, consult the chart on this page to select systems that are recommended within that range. Roof loads are also covered to aid in the selection of roof structural systems.

If a building will have multiple uses, read from the chart for the higher load range. Or, if the different uses will be physically separate within the building, the load ranges for each use may be applied to the appropriate areas.

# SOME TYPICAL CHOICES OF STRUCTURAL SYSTEMS FOR DIFFERENT BUILDING TYPES

Use the chart on these two facing pages to identify common structural systems used for various building types.

| | WOOD AND MASONRY | | | | | | | STEEL | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pages 58–65 | Pages 66–77 | Pages 72–73 | Pages 74–75 | Pages 76–77 | Pages 80–83 | Pages 86–89 | Pages 92–95 | Pages 102–103 | Page 104 | Page 105 | Page 106 | |
| **BUILDING TYPE** | **Platform Frame** | **Heavy Timber Frame** | **Glue-Laminated Beams** | **Trusses—Heavy** | **Glue-Laminated Arches** | **Brick Masonry Columns and Walls** | **Concrete Masonry Columns and Walls** | **Lightweight Steel Framing** | **Beams and Girders** | **Open-Web Joists** | **Single-Story Rigid Frames** | **Trusses** | **Long-Span Cables, Arches, Space Frames, Domes** |
| Arenas | | | | | | | | | ● | ● | | ● | ● |
| Concert halls | | | | | | | | | ● | | | ● | |
| Hospitals, laboratories | | | | | | ● | ● | | ● | ● | | ● | |
| Industrial & warehouse buildings | | ● | ● | ● | ● | ● | ● | | ● | ● | ● | ● | |
| Institutional, small to medium size | ● | | ● | | | ● | ● | ● | ● | ● | | | |
| Institutional, large | | | | | | | | | ● | ● | | ● | |
| Libraries | | | | | | | | | ● | | | | |
| Office buildings, small to medium size | ● | | ● | | | | ● | ● | ● | ● | | | |
| Parking garages | | | | | | | | | ● | | | | |
| Places of worship | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● | | |
| Residential, one- and two-family | ● | ● | | | | ● | ● | ● | | | | | |
| Residential, small to medium size | ● | | | | | ● | ● | ● | | | | | |
| Residential, large | | | | | | ● | ● | | ● | | | | |
| Schools | | | ● | | | ● | ● | | ● | ● | | | |
| Shopping malls | | | | | | ● | ● | | ● | ● | | | |
| Tall buildings | | | | | | | | | ● | | ● | | |
| Theaters | | | ● | | | ● | ● | | ● | ● | ● | ● | |

# SOME TYPICAL CHOICES OF STRUCTURAL SYSTEMS FOR DIFFERENT BUILDING TYPES

| SITECAST CONCRETE | | | | | | PRECAST CONCRETE | | |
|---|---|---|---|---|---|---|---|---|
| Pages 112–113 | Pages 114–115 | Pages 116–117 | Pages 118–119 | Pages 120–121 | Pages 122–123 | Pages 130–131 | Pages 132–133 | Pages 134–135 |
| Beams & Girders | One-Way Solid Slab | One-Way Joists | Two-Way Flat Plate | Two-Way Flat Slab | Waffle Slab | Beams and Girders | Solid and Hollow Core Slab | Single and Double Tee |
| ● | | | | | | | | |
| ● | ● | | | ● | ● | | | |
| ● | ● | | | ● | | ● | ● | |
| ● | ● | | | ● | | ● | ● | ● |
| ● | ● | | ● | | | | ● | |
| ● | ● | ● | ● | ● | | ● | ● | ● |
| ● | ● | | | ● | | | | |
| ● | ● | | ● | ● | | | ● | |
| ● | ● | ● | | ● | | ● | ● | ● |
| | | | | | | | | |
| | | | | | | | | |
| ● | ● | | ● | | | | ● | |
| ● | ● | | ● | | | | ● | |
| ● | ● | ● | | ● | ● | ● | ● | |
| ● | | | ● | ● | ● | ● | ● | |
| ● | | | ● | | | ● | ● | |
| ● | ● | ● | ● | | | ● | | |

# 2

# CONFIGURING THE STRUCTURAL SYSTEM

***This section will aid you in making a preliminary layout of the structural system of your building.***

## STABILIZING ELEMENTS

All buildings must be designed to resist lateral forces such as wind and earthquake. Three basic structural configurations may be used, either singly or in combination: the shear wall, the braced frame, and the rigid frame. The choice of the lateral force resisting system and the location of its elements will have a strong influence on the form of the building and the arrangement of its interior spaces.

### Shear Walls

*Shear walls* are solid walls constructed to resist the application of lateral forces. Though most often constructed of reinforced concrete, shear walls can be made of almost any structural material and range in size from small sections of panel-sheathed wood stud walls in residential buildings to massive steel and concrete structures in the tallest buildings. In comparison to the other systems described on this page, shear walls are especially stiff, making them a good choice wherever a relatively compact arrangement of stabilizing elements is desired. Shear walls must be mostly solid, with limited openings through the wall. To minimize interference with floor plan arrangements, shear walls are often incorporated into the building core, stair towers, or other vertical structures within the building. Shear walls can also be part of the exterior wall, although in this location they limit access to daylight and exterior views.

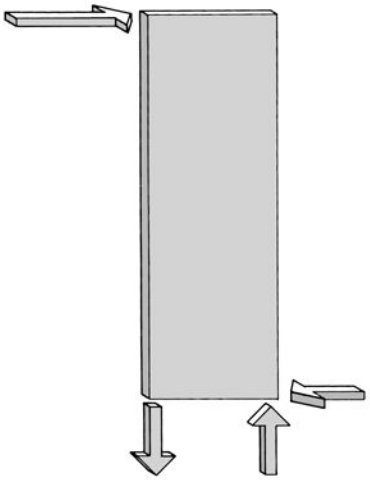
### Braced Frames

*Braced frames* are composed of open triangulated frameworks, most often constructed of steel or wood. In terms of strength per weight, they are the most efficient lateral force-stabilizing system. Like shear walls, braced frames are often incorporated into the building core or other vertical structures. They can also be part of exterior wall systems, where, in comparison to shear walls, their greater degree of openness results in less of an impact on daylight access and views.

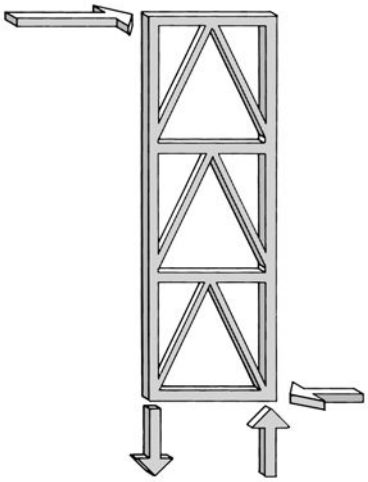
### Rigid Frames

*Rigid frames* depend on extra-stiff connections in the column-and-beam structural framework to resist the effects of lateral forces. These connections are most easily constructed in steel or sitecast concrete, though often at added cost in comparison to simpler, less rigid connections. Rigid connections may also be constructed in precast concrete, though with greater difficulty. The absence of solid panels or diagonal bracing makes this lateral force-resisting system attractive where the greatest flexibility in plan configuration is desired. However, the rigid frame is also the most structurally inefficient lateral force-resisting system. It is most suitable for low or broad structures requiring relatively modest resistance. In taller buildings, it is most frequently used in combination with either shear walls or braced frames. In addition, the rigid frame places greater stresses on the structural framework. Its application may result in columns and beams that are heavier or in columns more closely spaced than would otherwise be required.

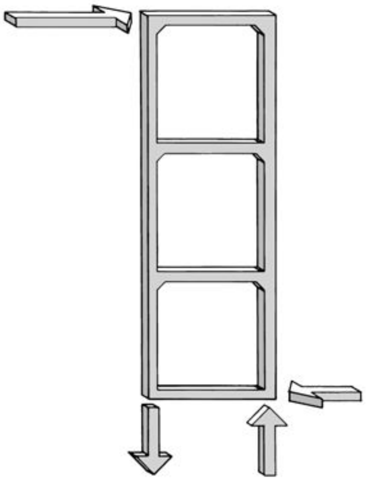
Connections with intermediate stiffness, termed *semirigid,* that are less expensive to construct, may also be used in combination with shear wall or braced frame lateral force-resisting systems.



**SHEAR WALL**



**BRACED FRAME**

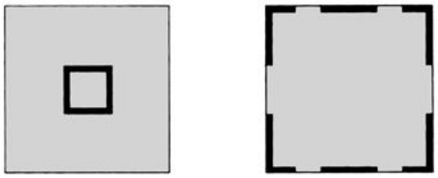


**RIGID FRAME**

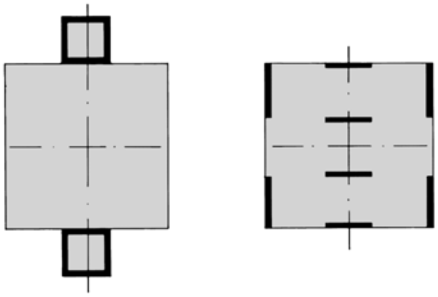
## CONFIGURING STABILIZING ELEMENTS

The arrangement of shear walls, braced frames, or rigid frames in a structure is important to their effectiveness in resisting lateral forces acting on the building. As illustrated in the adjacent schematic floor plans, these elements may be placed within the interior of the building or at the perimeter, and they may be combined in a variety of ways. However, they must be arranged so as to resist lateral forces acting from all directions. This is usually accomplished by aligning one set of stabilizing elements along each of the two perpendicular plan axes of the building. Stabilizing elements must also be arranged in balanced fashion in relation to the mass of the building. Unbalanced arrangements result in the displacement of the center of resistance of the building away from its center of mass. This condition may lead to difficult-to-control building movements under lateral load conditions.

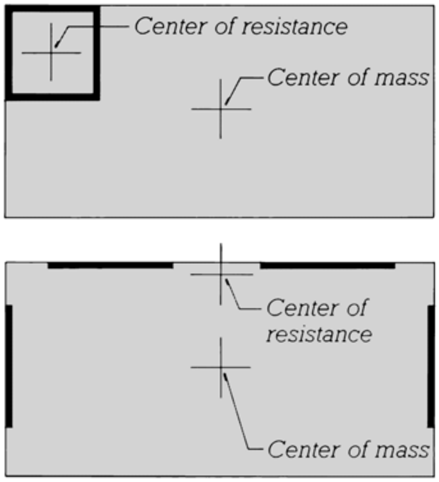
In general, lateral force-resisting elements are heaviest and most extensive at the base of a building, and diminish in size and extent as they approach the top of the building. In addition, considerations of lateral stability become increasingly important as the height of the building increases. The configuration of stabilizing elements is discussed further on the following pages.



***Stabilizing elements may be placed within the interior or at the perimeter of a building.***



***Stabilizing elements should be arranged in a balanced fashion and to resist lateral forces from any direction.***



***Avoid unbalanced arrangements of stabilizing elements that result in the displacement of the center of resistance of the building away from its center of mass.***

# LATERAL STABILITY AND STRUCTURAL SYSTEMS

## SELECTING STABILIZING ELEMENTS

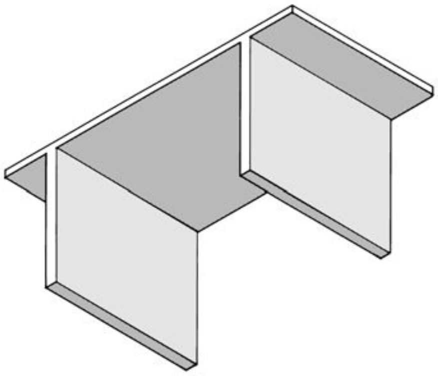
This chart indicates the methods of resisting lateral forces most common for each structural system. More detailed information on the structural systems can be found on the pages noted in the chart.

| STRUCTURAL SYSTEM | | Pages | Rigid Frame | Semi-Rigid Joints w/Supplemental Braced Frame or Shear Wall | Braced Frame | Shear Wall |
|---|---|---|---|---|---|---|
| **WOOD** | Platform Frame | 58–65 | | | ● Let-in bracing | ● Panel sheathing |
| | Heavy Timber Frame | 66–77 | ● Glue Laminated | | ● Timber bracing | ● Diagonal or panel sheathing |
| **MASONRY** | Ordinary Construction | 79–90 | | | | ● Masonry walls |
| | Mill Construction | 79–90 | | | | ● Masonry walls |
| **STEEL** | Light Gauge Steel Framing | 92–95 | | | ● Strap bracing | ● Panel sheathing |
| | Single-Story Rigid Frame | 105 | ● Parallel to frames only | | ● Perpendicular to frames | |
| | Conventional Steel Frame | 96–104 | ● Requires welded connections | ● | ● | ● Sitecast concrete |
| **SITECAST CONCRETE** | One-Way Solid Slab | 114–115 | ○ May require added structure | ● | | |
| | One-Way Beam and Slab | 114–115 | ● | ● | | |
| | One-Way Joist | 116–117 | ● | ● | | |
| | Two-Way Flat Plate | 118–119 | ○ May require added structure | ● | | |
| | Two-Way Flat Slab | 120–121 | ○ May require added structure | ● | | |
| | Waffle Slab | 122–123 | ● | ● | | |
| | Two-Way Beam and Slab | 118–119 | ● | ● | | |
| **PRECAST CONCRETE** | Solid Slab | 132–133 | ○ With special connection design | | ○ Uncommon | ● |
| | Hollow Core Slab | 132–133 | ○ With special connection design | | ○ Uncommon | ● |
| | Double Tee | 134–135 | ○ With special connection design | | ○ Uncommon | ● |
| | Single Tee | 134–135 | ○ With special connection design | | ○ Uncommon | ● |

● Recommended
○ Feasible in some circumstances, but less common

## VERTICAL LOAD-RESISTING ELEMENTS

Wall and slab systems are composed of loadbearing walls spanned by horizontal slabs. The placement of walls is restricted, as they must be located to support the loads from slabs and walls above. Due to the significant presence of the walls in the plan of the building, the use of a wall and slab system generally implies a close correspondence between the structural module and the planning of building functions. In addition, economic considerations usually dictate that the arrangement of walls be as uniform as possible, making this system particularly attractive for building types that require regular arrangements of uniformly sized spaces, such as apartments, schools, and hotels.

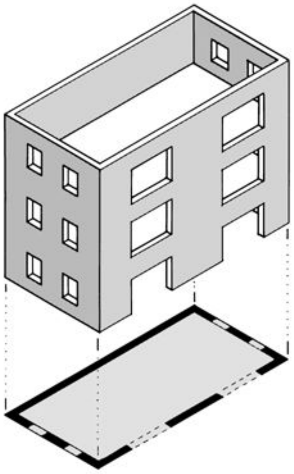


**WALL AND SLAB SYSTEMS**
***(shown from below)***

## LATERAL LOAD-RESISTING ELEMENTS

The regularly placed structural walls used in this system are often well suited to acting as shear walls for lateral stability. They may be used alone or combined with rigid frames or braced frames, for instance, where structural walls run in only one direction in a building.

When used alone, shear walls must be arranged to resist lateral forces in all directions, such as in some variation of a complete or partial box form. Shear walls should always be placed as symmetrically as possible in the building plan, particularly in taller buildings. The sizes and spacing of openings in shear walls generally need to be restricted as well.

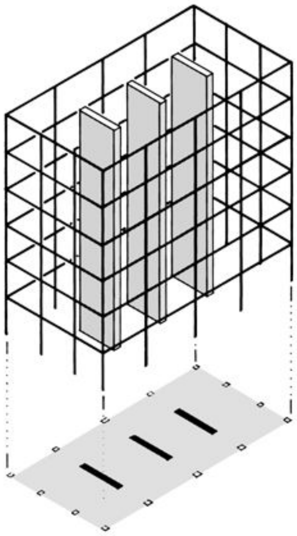


***Shear walls may be arranged in a box form to resist lateral forces from all directions.***

## SYSTEMS WELL SUITED TO WALL AND SLAB FRAMING

Bearing walls of any type may be used to create wall and slab structural systems. See the following sections for more information:

| Systems | Pages |
|---|---|
| Wood Stud Walls | 58–59 |
| Brick Masonry Walls | 82–83 |
| Concrete Masonry Walls | 88–89 |
| Lightweight Steel Stud Walls | 92–93 |
| Sitecast Concrete Walls | 110–111 |
| Precast Concrete Wall Panels | 128–129 |

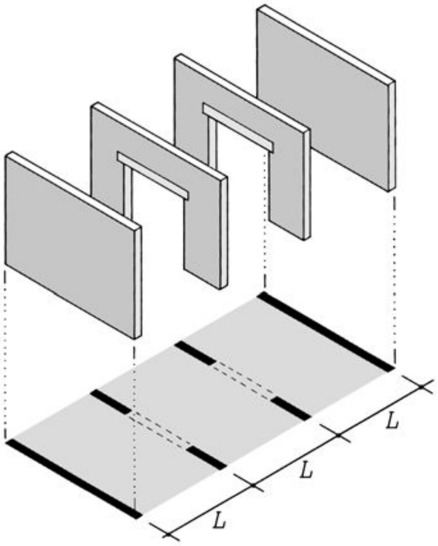


***When combined with other stabilizing mechanisms, shear walls may be arranged so as to resist forces in only one direction.***

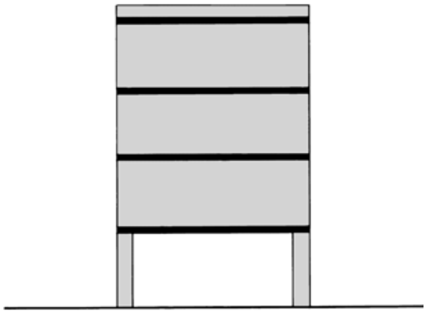
## WALL AND SLAB SYSTEM LAYOUTS

The distance between walls is equal to the span of the slab or floor system supported by the walls. Walls can be any length but are required wherever slabs are supported. Where necessary, openings in walls can be made by including beams over such openings to carry loads from above. In multistory buildings, the locations of bearing walls should coincide from floor to floor. However, where it is desirable to omit bearing walls from a lower floor, it may be possible to design the wall above as a deep beam supported at its ends only.

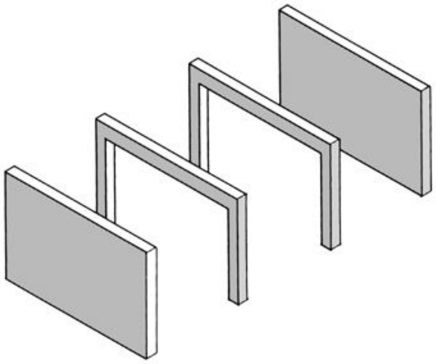
Wall and slab systems can be combined with column systems to permit greater open areas in a plan. Wherever possible, keep walls in locations that are most desirable for lateral load resistance.



***In wall and slab systems, the distance between walls is equal to the span of the slab above. Openings in walls may be made when beams are added to carry loads from above.***



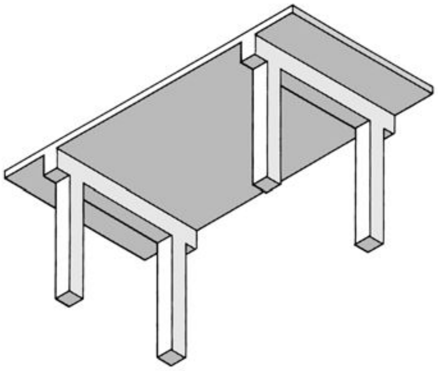
***Bearing walls may act as deep beams to span across openings below, as shown in this schematic cross section.***



***Bearing wall and column systems may be combined for more flexibility in plan layouts.***

## VERTICAL LOAD-RESISTING ELEMENTS

Column and beam systems are composed of vertical columns, horizontally spanning girders and beams, and slabs spanning between the beams. The columns in this system have less impact than loadbearing walls on the planning of spaces within a building. Where the sizes of interior spaces of a building do not correspond with a structural module, where maximum open space is desired, or where a high degree of flexibility in the use of space over time is desired, column and beam systems are a good choice. Compared to column and slab systems, column and beam systems are also practical over a greater range of spans and bay proportions.

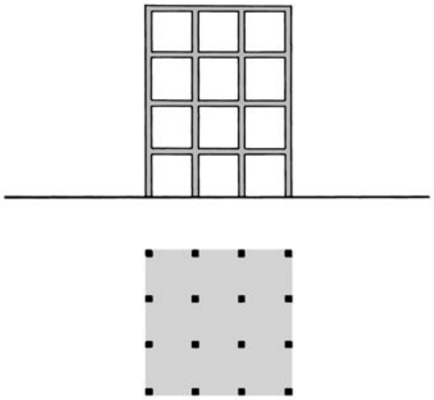


**COLUMN AND BEAM SYSTEMS**
***(shown from below)***

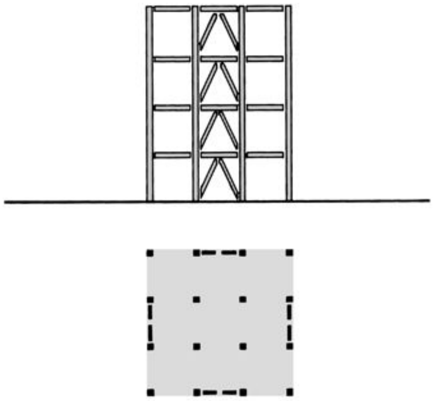
## LATERAL LOAD-RESISTING ELEMENTS

Column and beam systems of steel frame or sitecast concrete construction are well suited to rigid frame action. When used in this way, rigid joints are required at some or all column-to-beam connections. In sitecast concrete, rigid joints are produced as a normal feature of the system. In steel, rigid connections are generally more expensive to construct. Rigid joints are difficult to construct and are less frequently used in precast concrete structures. Because no added bracing or shear walls are required, rigid frame systems may be preferred for their minimal interference with the plan of a building. However, the use of rigid frames generally restricts column placements to regular orthogonal layouts, and often requires deeper beams and more closely spaced and larger columns than would otherwise be required with either braced frame or shear wall systems. Rigid frames are normally not well suited for structures with unusually long spans or tall columns.

When braced frames or shear walls are used for lateral stability, columns and beams may be joined with simpler hinged connections, such as the bolted connections normally used in steel and timber structures or the flexible welded connections used in precast concrete. The stabilizing braces or walls may be located within the interior of the building or at the perimeter, but they must be placed so as to resist lateral forces in all directions. Building cores or stair towers housing vertical circulation or other systems often can be designed to incorporate such elements, thus eliminating their intrusion into the remainder of the building floor plan. When located at the perimeter of the structure, these elements may influence the design of the building facade.



***Rigid frame structures require no additional bracing or shear walls, as shown in this elevation and plan.***



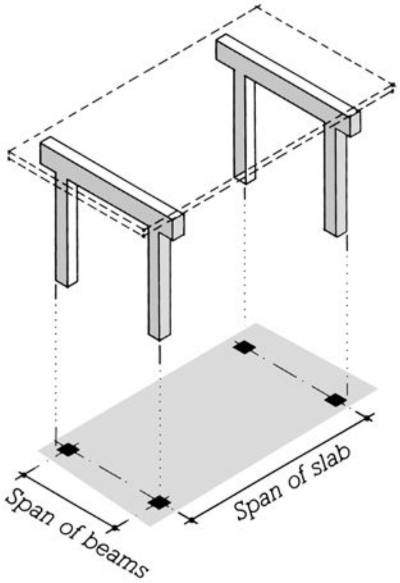
***The locations of braced frames or shear walls must be considered in relation to the elevation and plan of a building.***

# COLUMN AND BEAM SYSTEMS

## SYSTEMS WELL SUITED TO COLUMN AND BEAM FRAMING

Information on column and beam systems may be found in the following sections:

| Systems | Pages |
|---|---|
| Wood Beams | 70–71 |
| Steel Beams and Girders | 102–103 |
| Sitecast Concrete Beams and Girders | 112–113 |
| Precast Concrete Beams and Girders | 130–131 |



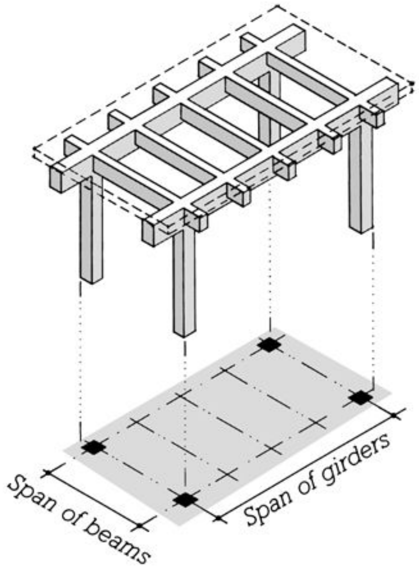
***In column and beam systems, columns are located on beam lines.***

## COLUMN AND BEAM SYSTEM LAYOUTS

Columns are located on the lines of the beams above. Although column spacings may vary within the limits of the spanning capacity of the beams, for reasons of economy, columns are typically restricted to some regular gridded arrangement.

Various combinations of beams and slabs are possible. Beams can span in one direction only, with slabs spanning perpendicular to them. With this arrangement, column spacing in one direction is equal to the span of the beams; in the other direction, it is equal to the span of the slabs.

More flexibility in the location of columns can be achieved with beams spanning in both directions. Deeper beams, termed *girders*, span the columns. The girders, in turn, support shallower secondary beams, spanning perpendicular to them. Finally, the distance between the secondary beams is spanned by the slab. Column spacings with such beam and girder arrangements are limited only by the spanning capacity of the beams in either direction. The choice of the direction of the span of the girders and beams in such a structure can be influenced by a variety of factors, including the relative structural efficiency of either arrangement, the lateral stability requirements for the overall structure, and the integration of the floor structure with other building systems such as electrical wiring in the slab or ducts and piping running beneath the floor framing. These considerations are covered in more detail in the sections of this book that discuss specific structural or mechanical systems.

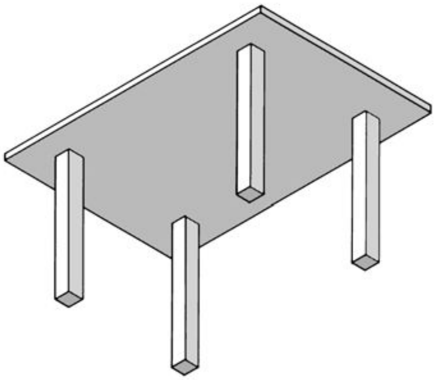


***Beams span both directions in beam and girder systems.***

# COLUMN AND SLAB SYSTEMS

## VERTICAL LOAD-RESISTING ELEMENTS

Column and slab systems are composed of vertical columns directly supporting horizontally spanning slabs without intermediary beams. As with column and beam systems, the reliance on columns for vertical load support permits greater independence between the building plan and the structural system. The absence of beams in column and slab systems may permit even greater flexibility in column placements than with column and beam systems, because columns are not restricted to beam lines. Column and slab systems may also be attractive economically due to the simplification of construction techniques and the reduction in total floor depths that they make possible. As discussed below, most column and slab systems are constructed of sitecast concrete.

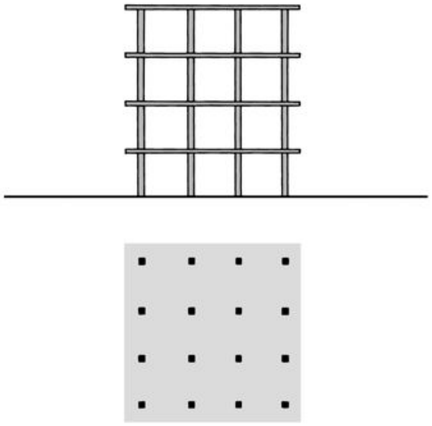


**COLUMN AND SLAB SYSTEMS**
***(shown from below)***

## LATERAL LOAD-RESISTING ELEMENTS

Rigid frame action is sometimes possible in column and slab systems, although its effectiveness depends on the depth of the slab, particularly in the areas close to the columns. Where large lateral forces are expected in systems with shallow slabs, a deepening of the slab or the addition of structural beams between columns may be required to achieve sufficient lateral force resistance.

Shear walls or braced frames may also be used to develop lateral resistance in column and slab systems. These elements may be used either as the sole means of lateral bracing or as enhancements to the rigid frame action of the system. They may be located within the interior of the building or at the perimeter, but they must be placed so as to resist lateral forces in all directions. The locations of interior elements must be coordinated with the building plan. Building cores housing vertical circulation or other systems can often be easily designed to incorporate such elements, thus eliminating their intrusion from the remainder of the floor plan. When located at the perimeter of the structure, shear walls or braces may influence the design of the building facade.

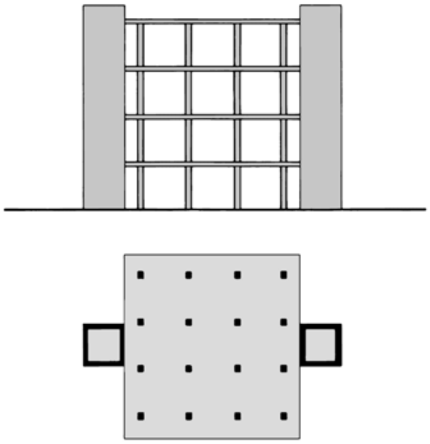


***As shown in this elevation and plan, rigid frame action is possible with column and slab systems, although its effectiveness may be limited.***

## SYSTEMS WELL SUITED TO COLUMN AND SLAB FRAMING

Conventional structural systems that are configured as column and slab systems are metal space frame, and a number of sitecast concrete systems, including two-way flat plate, two-way flat slab, and either one-way joist or waffle slab construction (when these two systems are used with shallow beams that do not extend below the surface of the ribs). For further information, see the following sections:

| **Systems** | **Pages** |
|---|---|
| Sitecast Concrete Two-Way Flat Plate | 118–119 |
| Sitecast Concrete Two-Way Flat Slab | 120–121 |
| Sitecast Concrete One-Way Joists | 116–117 |
| Sitecast Concrete Waffle Slab | 122–123 |



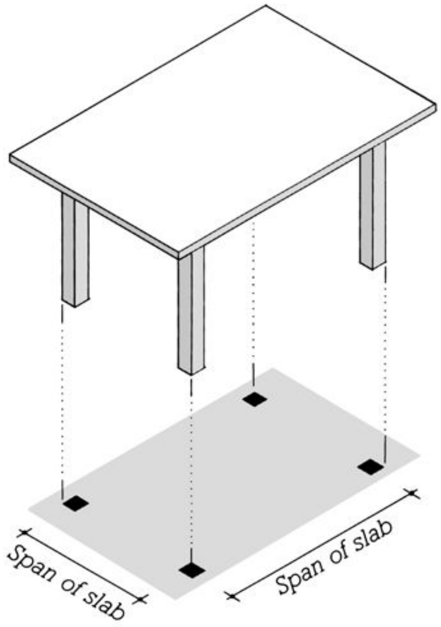
***Shear walls are frequently used with column and slab systems. In this elevation and plan, the shear walls are shown incorporated into a pair of vertical cores.***

## COLUMN AND SLAB SYSTEM LAYOUTS

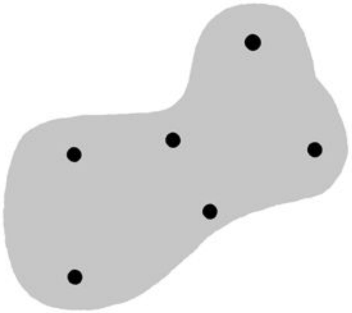
Column spacing in either direction is equal to the span of the slab. For maximum economy and structural efficiency, column bays should be roughly square in proportion and columns should be arranged along regularly spaced bearing lines. However, where driven by design considerations, column and slab systems can often more readily tolerate deviations in standard column placements, variations in bay sizes, and irregular plans shapes than other framing systems.

## STRUCTURAL LIMITATIONS OF COLUMN AND SLAB SYSTEMS

The absence of beams in sitecast concrete flat plate and flat slab construction imposes some limits on the structural performance of these systems. The relatively shallow depth of the joint between the columns and slabs can restrict their vertical load-carrying capacity and limit their resistance to lateral forces. Though the addition of beams to these systems adds substantially to construction costs, it may be a practical alternative where longer spans are required, very heavy loads must be carried, or additional lateral resistance is needed and the use of shear walls or braced frames is undesirable. Such configurations are covered in more detail in the sections describing these structural systems.



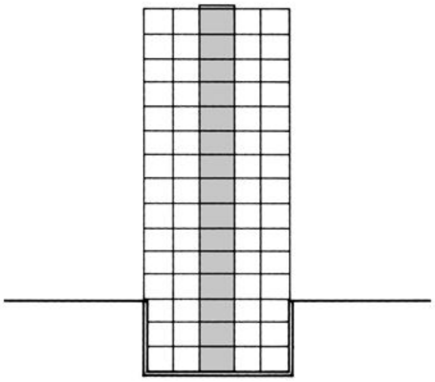
***In column and slab systems, the span of the slab is equal to the column spacing in either direction.***



***The absence of beams in column and slab systems facilitates irregular column layouts or plan shapes.***

## THE DESIGN OF TALL BUILDING STRUCTURES

As a building's height increases, the design of its structural system becomes increasingly specialized. Factors that may influence the selection, form, and configuration of a tall building structure include the cumulative effect of large vertical loads; site-specific conditions related to wind, earthquake, and soils; the regional availability and costs of various construction systems; and spatial requirements of the building program. The information on the following pages describes structural options available for a tall building design in relation to some of these considerations. However, it cannot fully address them all. For this reason, the design of such structures should also include the participation of the structural designer from the earliest phases of design.



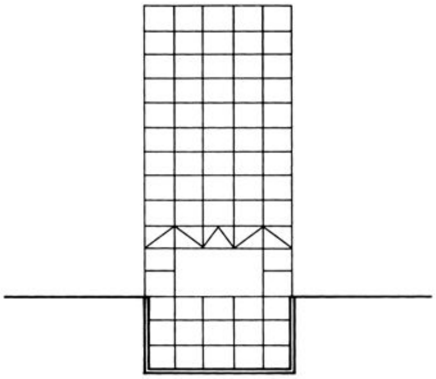
***Major loadbearing elements should be continuous vertically to the foundations of the building.***

## VERTICAL LOAD–RESISTING SYSTEMS

The vertical load-resisting systems for mid- and high-rise buildings are essentially variations on those for low-rise structures described on the previous pages. In the tallest buildings, column and beam systems are most common due to their efficient use of space, structural versatility, and ease of construction.

Because of the large gravity loads associated with taller structures, special care should be taken that major structural elements are not interrupted vertically. To the greatest extent possible, building core structures, columns, and other loadbearing elements should extend continuously to the foundation, and should avoid offsets from floor to floor or other vertical discontinuities.

Nevertheless, conditions may arise in which not all loadbearing elements can have direct and continuous paths to the building's foundation: In very tall buildings, it is often structurally advantageous to redistribute vertical loads outward toward the building corners to increase resistance to overturning; larger open spaces in lower floors, such as commercial areas, public auditoriums, lobbies, or atria, may require column-free configurations that interrupt the paths of structural elements from above; or other variations in program requirements or building massing may necessitate significant shifts in the arrangement of structural elements. In such cases, where only minor changes in load paths are required, columns may be subtly sloped or shifted between floors. Where more significant redistributions of load are required, transfer beams or heavy, long-span truss structures may be used. In other cases, changes in the selection of structural system or its basic configuration and design may be appropriate.



***Transfer beams or trusses may be used to interrupt vertical loadbearing elements where necessary.***

## LATERAL LOAD-RESISTING SYSTEMS

Increasing the height of a building increases especially its sensitivity to wind and earthquake forces. The taller the building, the more these forces will dictate the design of the structure, and the more the influence of these forces on building form should be considered during preliminary design. The following guidelines are particularly important in the design of very tall buildings.

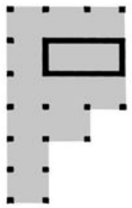
As building height increases, expect the lateral support system to increase in prominence within the design. Lateral force-resisting elements may become heavier, may be more closely spaced, or may increase in horizontal extent, and the choice of suitable systems and their configuration may become more constrained.

Designs that are asymmetric in plan, that are unbalanced in their massing, or that have irregular arrangements of stabilizing elements become increasingly problematic in taller buildings. Under the influence of lateral loads, these conditions can lead to difficult-to-control building motions or excessive stresses in structural elements. These conditions should be avoided to the maximum extent possible.

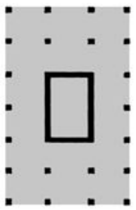
Where large buildings are composed of discrete masses, each part can be expected to move differently under the conditions associated with lateral loads. The leg of an L-shaped building, the stem of a T-shaped building, a tower offset to one corner of a wider base, or other such irregular arrangements are prone to adverse interactions under dynamic conditions. Where such conditions occur, each mass should be designed as an independent structure, with substantial joints between the abutting masses that can safely absorb differential movements between them.

Buildings of inherently unstable massing or form should be avoided. Large or irregular openings in floor plates are detrimental, especially those constituting 50% or more of the overall floor area. Discontinuities in the stiffness of a structure at different levels should be avoided. For example, an open space with long horizontal spans at the base of a tall building can produce excessive flexibility or weakness at that level. If such a "soft story" cannot be avoided, extra care to provide adequate lateral support at that level may be required.

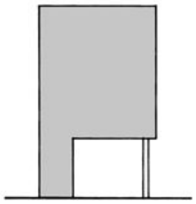
Tall buildings may interact with the wind in a variety of ways that do not lend themselves to simple generalizations. Wind forces can cause excessive deflection or twisting of the building structure, lateral accelerations that are uncomfortable for occupants, or localized areas of high pressure acting on the facade. As the wind moves over and around the building, it can also cause uncomfortably high air speeds at the base of the building or other nearby areas, or have secondary impacts on downwind structures. Because of the complexity of these effects, designs for very tall buildings are typically subject to mathematical wind modeling and wind tunnel testing even at early phases of design. The results of this modeling and testing are used to minimize adverse effects through adjustments in building massing, structural response, facade orientation, and surface articulation.



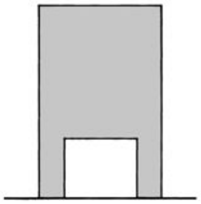
**UNBALANCED PLAN**



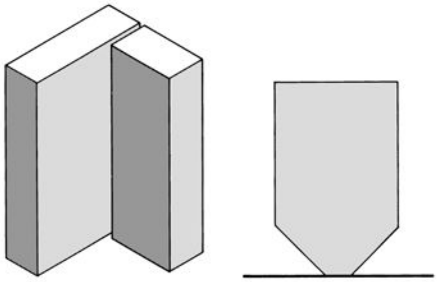
**BALANCED PLAN**



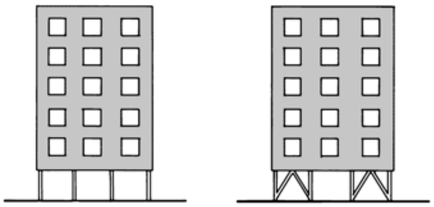
**UNBALANCED SECTION**



**BALANCED SECTION**



*Discrete building masses should be structurally independent. Inherently unstable building masses should be avoided.*



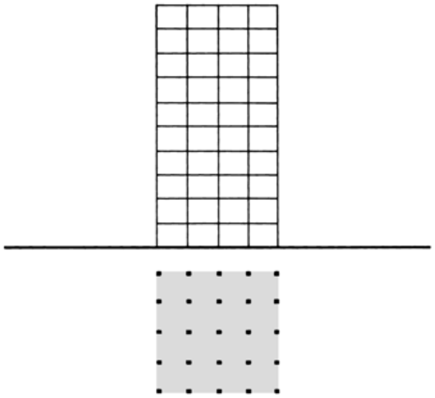
*Discontinuities in the stiffness of structures at different levels should be avoided, or additional stabilizing elements may be required.*

# TALL BUILDING STRUCTURES

As building height increases, the three basic systems of lateral force resistance—shear wall, braced frame, and rigid frame—may be employed in unique ways. The following tall building configurations are presented in order of suitability for structures of increasing height. The adjacent diagrams illustrate schematically in both plan and section each of the configurations described.

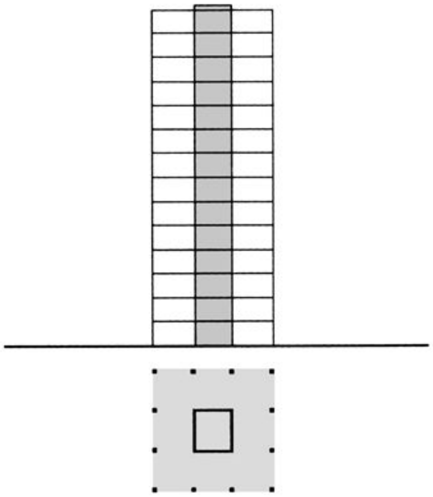
## CONVENTIONAL STRUCTURAL CONFIGURATIONS

The conventional arrangements of stabilizing elements used in low-rise buildings may be extended for use in buildings up to 20 to 25 stories in height. The same considerations that apply to low-rise buildings apply to taller buildings as well: Stabilizing elements should be arranged so as to resist lateral forces along all major axes of the building. These elements should be arranged in a balanced manner either within the building or at the perimeter. And such elements must be integrated with the building plan or elevation.

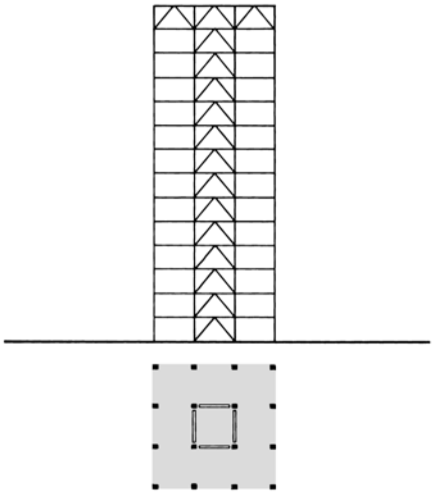


**RIGID FRAME**

Shear walls and braced frames are the stabilizing elements most commonly used in buildings of this height, due to their structural efficiency. They may be used either separately or in combination. The use of rigid frame systems as the sole means of achieving lateral stability may be feasible in buildings up to 15–20 stories in height in areas of low seismic activity, or somewhat less in height in areas of greater seismic activity. However, even where feasible, rigid frame structures may be a less attractive option due to the greater difficulty of their fabrication and the increased size of the beams and columns required. More commonly in buildings of this height, rigid frame components are used in combination with either shear walls or braced frames to enhance the lateral resistance of the structure as a whole.



**RIGID CORE**



**BRACED CORE WITH HAT TRUSS**

## CORE STRUCTURES

Core structures are the most commonly used system to stabilize tall buildings. The enclosures at the center of the building, used to house vertical circulation and other building systems, are structured to also serve as stabilizing elements. One of the principal advantages of core structures is that with the placement of the resisting elements in the building core, interference with the surrounding usable space is minimized. In concrete construction, core walls already intended to enclose building systems can easily be designed to also act as shear walls. In steel construction, core structures are usually designed as braced frames.

A single core servicing an entire building should be located at the center of the building. In buildings with more than one core, the cores should be located symmetrically in the building plan so as to provide balanced resistance under lateral loads from any direction. Cores typically comprise approximately 20%–25% of the total floor area of a mid- or high-rise building. They should be formed as closed elements, approximately square or cylindrical, with openings into the core kept to a minimum.

Simple core structures can be used in buildings as high as 35 to 40 stories. Core structures can also be enhanced structurally with *hat trusses* (at the top of the structure) or *belt trusses* (at points lower down) that engage the perimeter's structural elements in the resistance to lateral loads, thus improving the performance of the building as a whole. These elements may become aesthetically expressed on the building facade or may be preferred locations for mechanical floors. Columns at the perimeter of the building may also increase in size with these systems. These core-interactive structures are suitable for buildings up to approximately 60 stories in height.

For further information on the design of building cores to accommodate mechanical and circulation systems, see pages 190–192.

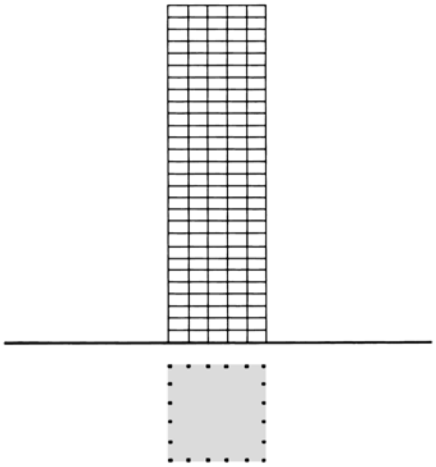
## TUBE STRUCTURES

Many of the world's tallest buildings are designed as tube structures. In this system, stabilizing elements are located at the perimeter of the structure, leaving the layout of the interior of the building unrestricted by considerations of lateral stability. Either braced frame or rigid frame elements, constructed from either steel or concrete, may be used. Simple tube structures and their variations are generally suitable for buildings approximately 55 stories or greater in height.

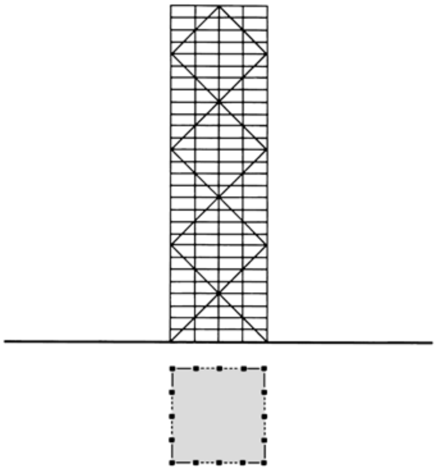
The use of rigid frame tubes may affect the size and spacing of framing elements at the perimeter of the building. Beams may need to be deeper and columns may need to be larger and more closely spaced than would otherwise be required. When building in steel, the welded joints required in this system may be more costly to construct, although construction systems have been developed that allow the off-site fabrication of these joints, minimizing this disadvantage. And as with core structures, the performance of rigid frame tubes may be enhanced with hat trusses or belt trusses integrated within the perimeter structure.

Braced frame tubes are highly structurally efficient lateral load-resisting configurations. When built in steel, these structures rely on more easily constructed hinged connections. The diagonal braces that are an integral part of this system often have a significant impact on the appearance of the building facade.

Variations on the tube structure and other tall building configurations are also possible. Tube-in-tube structures allow perimeter tubes to interact with rigid cores. Bundled tube structures allow greater variation in building massing. Space truss structures are similar to braced tubes, with the addition of large-scale diagonals that pass through the building's interior. Diagrid structures rely on latticed frameworks that carry both vertical and lateral loads, with few or no vertical columns.



**RIGID FRAME TUBE**

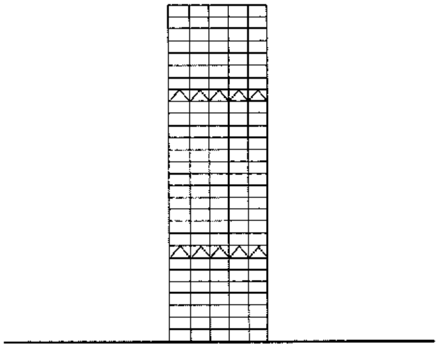


**BRACED FRAME TUBE**

## PRACTICAL LIMITS ON THE HEIGHT OF TALL BUILDINGS

At the time of this writing, the world's tallest completed building is Dubai's Burj Khalifa Tower, with 160 habitable floors and a height of 2717 ft (828 m). For most of its height, this building is constructed as a sitecast concrete flat plate, wall and slab structure. For lateral stability, this structure relies on a central concrete core buttressed by heavy shear walls radiating to the tower extremities.

When considering the width of tall buildings, those with a slenderness ratio of 5 or more (ratio of the height to least plan dimension at the base of the building) should be considered increasingly challenging from the point of view of ensuring lateral stability. The most slender tall buildings are 10 to 15 times as tall as they are wide.



**RIGID FRAME TUBE WITH BELT TRUSSES**

## SPECIAL CONSIDERATIONS IN THE DESIGN OF TALL STRUCTURES

### Steel Structural Systems

Structural steel is well suited to the construction of tall buildings. The light weight of steel in relation to its strength results in a building of relatively low mass, thereby reducing the amount of structure and foundation required to support the weight of the building itself. This characteristic also results in columns and other structural elements of lesser size, minimizing their consumption of space within the building that could otherwise be productively used by its occupants or devoted to other building systems.

Structural steel also has particular advantages for buildings located in areas of high seismic activity. A lower-mass structure experiences lower forces during an earthquake. In addition, the high ductility of steel (its ability to resist repeated high levels of stress without failure) allows for the design of a structure capable of resisting extreme loads and dissipating the large quantities of dynamic energy imparted to it during sustained earthquake shaking. Designing a building frame that takes full advantage of these characteristics will result in a structure that is flexible, resilient, and capable of safely withstanding severe seismic events.

### Concrete Structural Systems

In comparison to structural steel, concrete is a more massive and less ductile material. For these reasons, it has traditionally been considered to be at a disadvantage for the design of tall buildings. Especially when the effects of earthquake loads are considered, the higher mass of concrete implies higher forces acting on the structure. This material's lesser ductility also makes it less capable of absorbing the dynamic energy imparted to it during sustained earthquake loading. However, in recent years, higher-strength concretes have been developed, and a better understanding has been gained of the design of steel reinforcing to create ductility within a concrete structure. With these developments, concrete's disadvantages in comparison to steel have been minimized, and it remains a viable choice as a structural material for buildings of any height.

Concrete's unique characteristics can also be advantageous. Concrete is tough and resistant to impact, and unlike steel, it usually does not require a separate covering to protect it from the heat of building fires. Because concrete structures typically undergo smaller deflections than ones constructed of structural steel, the detailing of connections to nonstructural elements such as cladding and partitions may be simplified, and the performance of these elements under severe load conditions may be less problematic. The great stiffness of concrete shear walls is well suited to structures where there is a desire to keep the stabilizing elements compact, and to very slender structures where there is insufficient depth to make effective use of alternative stabilizing systems. Even in areas of high seismicity, the greater stiffness of concrete structures may be well suited to building sites where ground movements associated with earthquakes are such that the shorter period of vibration of a stiffer structure is advantageous.

Concrete is also frequently used together with steel in ways that exploit the attributes of both materials simultaneously. For example, composite columns made of steel box shapes filled with high-strength concrete can achieve very high load-carrying capacity. Such composite columns form a primary structural element in one of the world's tallest buildings, the Taipei 101. At the base of this building, each of eight "supercolumns" measures almost 8 × 10 ft (2.4 × 3.0 m) in section. Even in building structures nominally described as steel, concrete core structures and floor systems commonly play critical roles as well.

### Damping Mechanisms for Resisting Lateral Forces

A tall building structure's response to the effects of wind or earthquake can be enhanced with devices designed to dampen the movements imparted to it by these loads. *Viscous dampers* are shock-absorber-like devices. They may be incorporated into parts of the building frame, where they can reduce building deflections during high lateral loading as well as increase the structure's energy-absorbing capacity.

Viscous dampers may also be combined with a system of *base isolators* at the foundation of the building. This arrangement allows a degree of separation between the building structure and the ground upon which it rests. In the event of an earthquake, a significant portion of the ground motion that occurs is never transmitted into the building structure at all. Meanwhile, the dampers act to prevent the structure from drifting beyond the physical limits of the isolation system. In severe earthquake zones, base isolation and damper systems accommodating displacements of up to 30 in. (760 mm) or more may be used. When considering base isolation systems, the designer should make allowance for the displacements that are to be expected between the building and the adjacent ground. Utility lines will require flexible connections where they enter the foundation. Connections to exterior stairs, plazas, sidewalks, and adjacent buildings must also be able to accommodate the differential movements that this system allows.

*Tuned mass dampers* may be used to control deflection or "side sway" in tall buildings. These are heavy masses, suspended, pendulum-like, within the building structure, usually near its top, and connected to it by an array of dampers similar to those discussed above. As wind forces act to deflect the structure sideways, the inertia of the suspended mass resists these movements and reduces the magnitude of the sideways deflection. The rates at which the structure accelerates as it periodically reverses its sway can also be reduced, an important consideration for occupant comfort. More recently, *tuned liquid dampers* consisting of water tanks with specially configured internal chambers and baffles have been designed to work in a similar manner.

*Active dampers* rely on sensors placed near the top of the building structure that measure accelerations in real time. This information is processed and then used to command hydraulic activators that exert counteracting forces on portions of the structure, thereby controlling structural movements. Active systems may not be suitable for use in areas of high seismic activity, where loss of power during earthquakes could render the system inoperable.

Such dampening systems can be useful in very tall buildings where the discomfort caused by building sway frequently becomes the controlling factor in the structural design. By reducing lateral deflections and lessening accelerations, these systems allow satisfactory structural performance in structures of less weight and lower cost.

# 3

# SIZING THE STRUCTURAL SYSTEM

***This section will assist you in assigning approximate sizes to structural elements. Additional information on designing and building with each structural system is also provided.***

# WOOD STRUCTURAL SYSTEMS

Wood construction typically takes one of two distinct forms: *Wood Light Frame Construction* uses relatively thin, closely spaced members to form walls, floors, and roofs in a system also called *platform frame construction*. *Heavy Timber Construction* uses larger members configured as a post and beam system. Both of these systems are fully treated in this section.

Both Wood Light Frame and Heavy Timber Construction can be combined with masonry construction for increased fire resistance and load capacity. These systems are more fully described under Masonry Structural Systems, beginning on page 79.

## PLATFORM FRAME CONSTRUCTION

Platform Frame Construction is an economical and flexible building system. It is used extensively for single-family and multifamily housing, as well as for low-rise residential buildings and small commercial structures.

Because this system is largely fabricated on-site and individual framing members are small, it is also well suited for use where irregular forms are desired. Where economy is a primary concern, the use of a 2- or 4-ft (600- or 1200-mm) modular plan dimension will reduce waste. Platform Frame Construction easily and unobtrusively incorporates mechanical systems and other building services.

Platform framing is a wall and slab system. Lateral bracing may be supplied either by shear wall or braced frame action of the walls. Information on the components of Platform Frame Construction can be found on pages 58–65.

## HEAVY TIMBER CONSTRUCTION

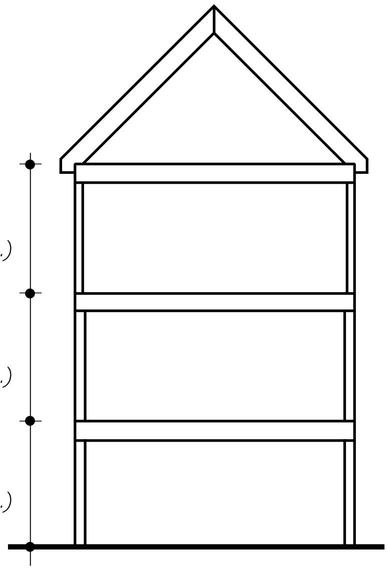
Heavy Timber Construction is characterized by good fire resistance (it has a higher fire rating than unprotected steel), high load capacity, and the unique aesthetic qualities of the exposed wood frame. The framing members for Heavy Timber Construction may be either solid wood or glue-laminated. Heavy timber frames are used for low-rise commercial and industrial buildings and in residential construction. Because the framing members are typically prefabricated, on-site erection times can be rapid with this system. However, the larger sizes of the framing members make this system less suitable than platform framing for structures that are highly irregular in form or layout. Mechanical and electrical systems are also often less easily concealed in this system.

As in platform framing, economy of construction may be maximized with the use of a 2- or 4-ft (600- or 1200-m) design module when planning a timber frame structure.

Timber frames may be stabilized laterally by the shear resistance of the walls or panels used to enclose the frame or with diagonal bracing elements. The masonry bearing walls of Ordinary or Mill Construction (page 79) are also well suited to acting as shear walls. Information on the components of Heavy Timber Construction can be found on pages 66–77.

## WOOD STUD WALLS—CONVENTIONAL CONSTRUCTION

Use the diagram below to select a wood stud size and spacing for conventional low-rise light wood frame residences and buildings. For wood stud walls designed for a wider variety of loading and span conditions, use the charts on the opposite page.



*Studs supporting roof only:*
*2 × 4 @ 24" o.c. (38 × 89 mm @ 600 mm o.c.)*
*2 × 6 @ 24" o.c. (38 × 140 mm @ 600 mm o.c.)*

*Studs supporting one floor and roof:*
*2 × 4 @ 16" o.c. (38 × 89 mm @ 400 mm o.c.)*
*2 × 6 @ 24" o.c. (38 × 140 mm @ 600 mm o.c.)*

*Studs supporting two floors and roof:*
*2 × 6 @ 16" o.c. (38 × 140 mm @ 400 mm o.c.)*

### ACTUAL SIZES OF WALL STUDS

| Nominal Size | Actual Size |
|---|---|
| 2 × 4 | 1½" × 3½" (38 × 89 mm) |
| 2 × 6 | 1½" × 5½" (38 × 140 mm) |
| 2 × 8 | 1½" × 7¼" (38 × 184 mm) |

## WOOD STRENGTH

When reading the charts on the opposite page, examples of strong woods include Select Structural grades of Douglas Fir, Larch, Hemlock, or Southern Pine. Examples of average-strength woods include No. 2 grades of Hem-Fir or Spruce-Pine-Fir. For other species and grade combinations of intermediate strength, you may interpolate between the results charted for these two groups.

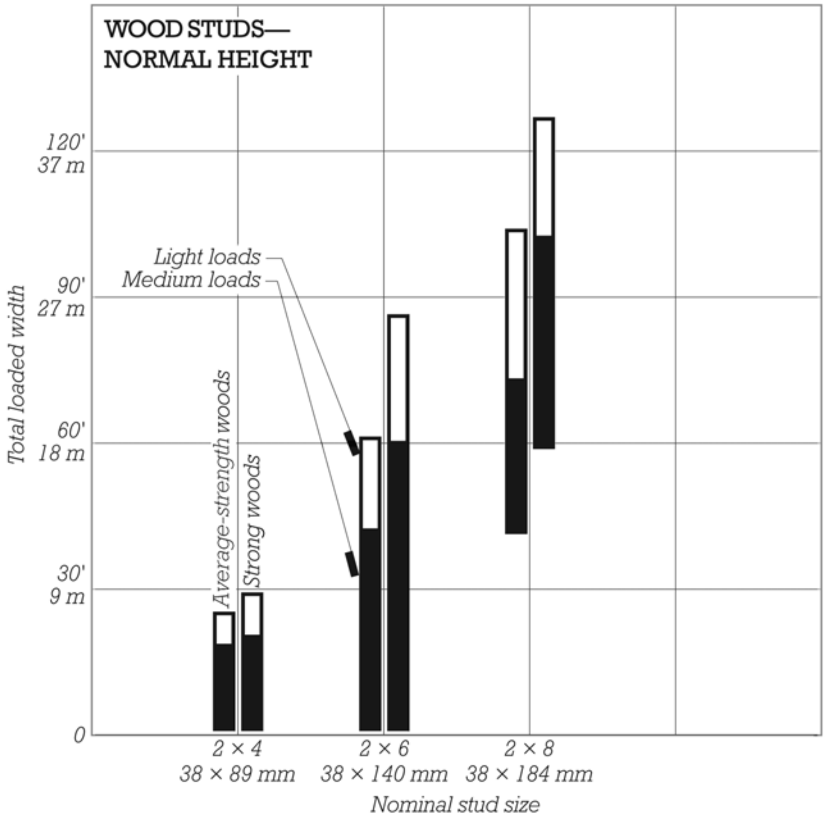
## SPACING OF WALL STUDS

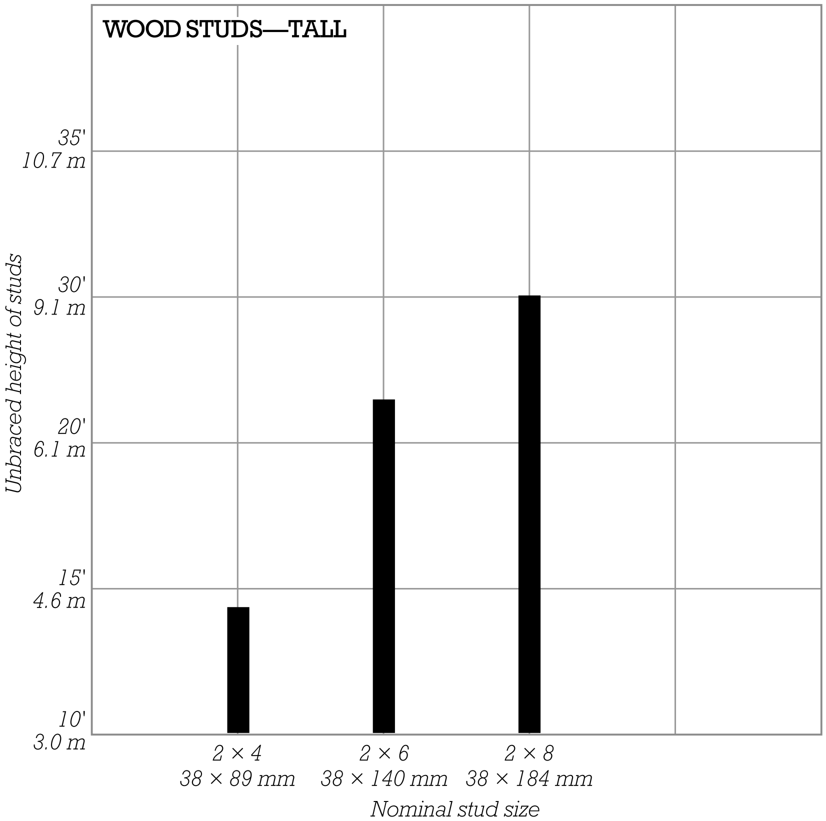
Wall studs are most commonly spaced at 16 or 24 in. (400 or 600 mm) on center. A 12-in. (300-mm) spacing may be used where greater loads must be supported. Studs should always be spaced within a 4-ft (1200-mm) module in order to coordinate with the standard width of various sheathing and wallboard products that are commonly used with this type of construction.

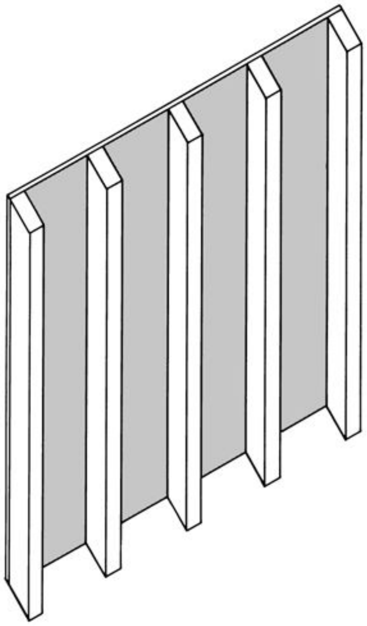
## FIRE-RESISTANCE RATINGS FOR WOOD STUDS

Wood stud walls may be used in Ordinary Construction and Wood Light Frame Construction. Framing covered with one layer of ⅝-in. (16-mm) Type X gypsum wallboard or its equivalent on each side can achieve a 1-hour fire-resistance rating. With two layers on each side, a 2-hour rating can be achieved.

# WOOD STUD WALLS







The top chart is for loadbearing wood stud walls up to 10 ft (3.0 m) in height. For each nominal stud size, read from the right-hand bar for strong woods or from the left-hand bar for average-strength woods. Read in the top open areas for light loads or in the lower solid areas for medium loads. *Total loaded width* is the tributary width of one floor (one-half of its span) multiplied by the number of floors and roof above the wall.

For stud walls taller than 10 ft (3.0 m), read from both charts on this page, using the larger size indicated by either chart. *Unbraced height of studs* is the vertical distance between floors or other supports that brace the studs laterally against buckling.

■ On the lower chart, for strong woods, light loads, and close stud spacing, read toward the top in the indicated areas. For average-strength woods, heavy loads, and greater stud spacing, read toward the bottom.

■ Wall height may be increased with the addition of intermediate bracing perpendicular to the wall plane.

## ACTUAL SIZES OF FLOOR JOISTS

For the actual size of solid wood joists, read from the following table. I-joists are listed in actual size.

| Nominal Size | Actual Size | |
|---|---|---|
| 2 × 6 | 1½" × 5½" | (38 × 140 mm) |
| 2 × 8 | 1½" × 7¼" | (38 × 184 mm) |
| 2 × 10 | 1½" × 9¼" | (38 × 235 mm) |
| 2 × 12 | 1½" × 11¼" | (38 × 286 mm) |

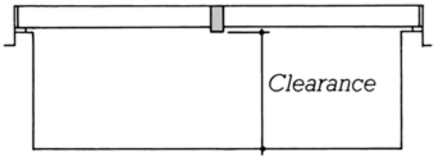
## TOTAL FINISHED FLOOR THICKNESS

To estimate total finished floor thickness, add 2 to 3 in. (50 to 75 mm) to the actual joist size to account for conventional subflooring and finish materials.

## BEAMS SUPPORTING FLOOR FRAMING

### Wood Beams

For sizing wood beams, see the chart on page 71. To determine clearance under a wood beam, assume that the top of the beam is level with the top of the floor joists.

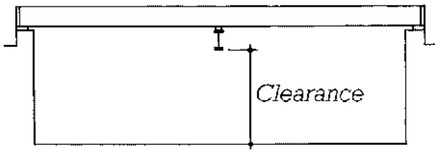


JOISTS WITH WOOD FLOOR BEAM

### Steel Beams

| Beam Size | Approximate Depth of Beam | Span of Beam |
|---|---|---|
| W8 | 8" (205 mm) | 8'–13' (2.4–4.0 m) |
| W10 | 10" (255 mm) | 10'–16' (3.0–4.9 m) |
| W12 | 12" (305 mm) | 12'–18' (3.7–5.5 m) |

For lightly loaded beams, use the longer spans indicated. For heavily loaded beams, use the shorter spans. To determine clearance under a steel beam, assume that the top of the beam is level with the top of the foundation wall.

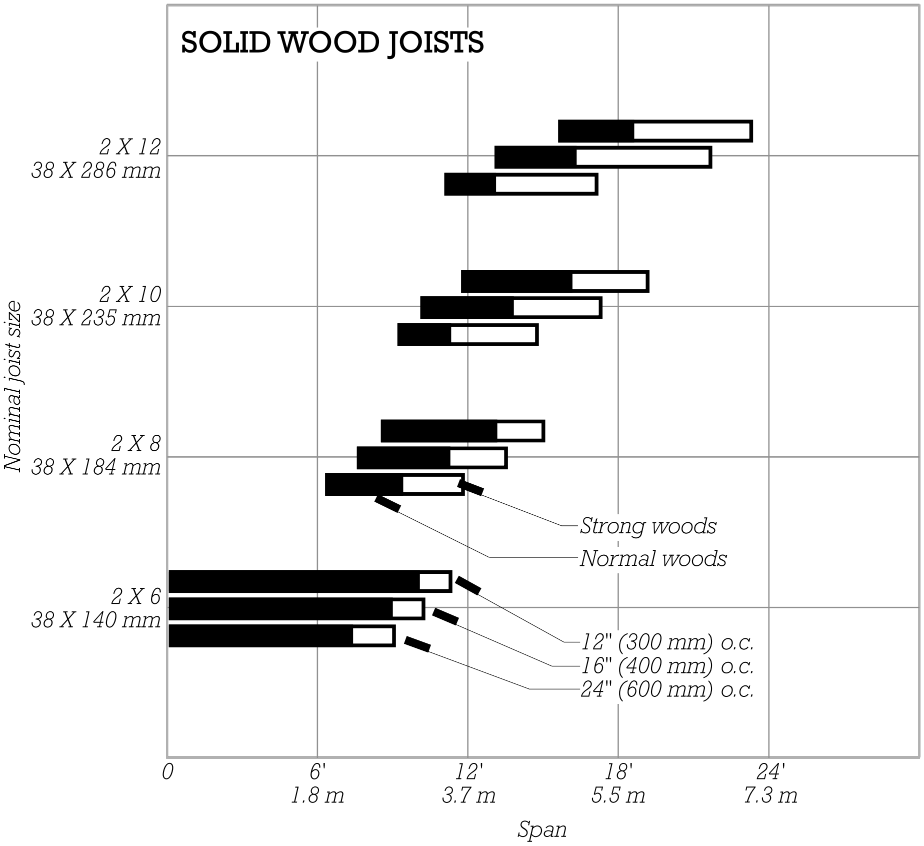


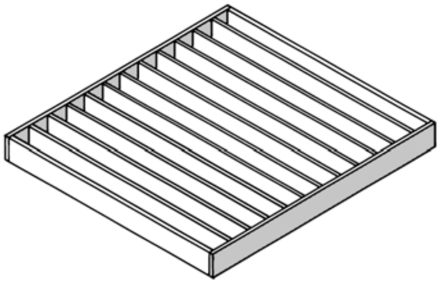
JOISTS WITH STEEL FLOOR BEAM

## FIRE-RESISTANCE RATINGS FOR WOOD LIGHT FRAME JOISTS

Wood floor joists may be used in Ordinary Construction and Wood Light Frame Construction. Floor/ceiling assemblies framed with solid wood joists and nominal 1-in. (19-mm) subflooring and finish flooring can achieve a 1-hour fire-resistance rating when the underside of the framing is finished with ⅝-in. (16-mm) Type X gypsum board or its equivalent. With I-joist framing, ⅝-in. (16-mm) furring channels may also be required. A 2-hour rating can be achieved with either solid or I-joist framing with two layers of ⅝-in. (16-mm) Type X gypsum board and ⅝-in. (16-mm) furring channels.

# WOOD FLOOR JOISTS

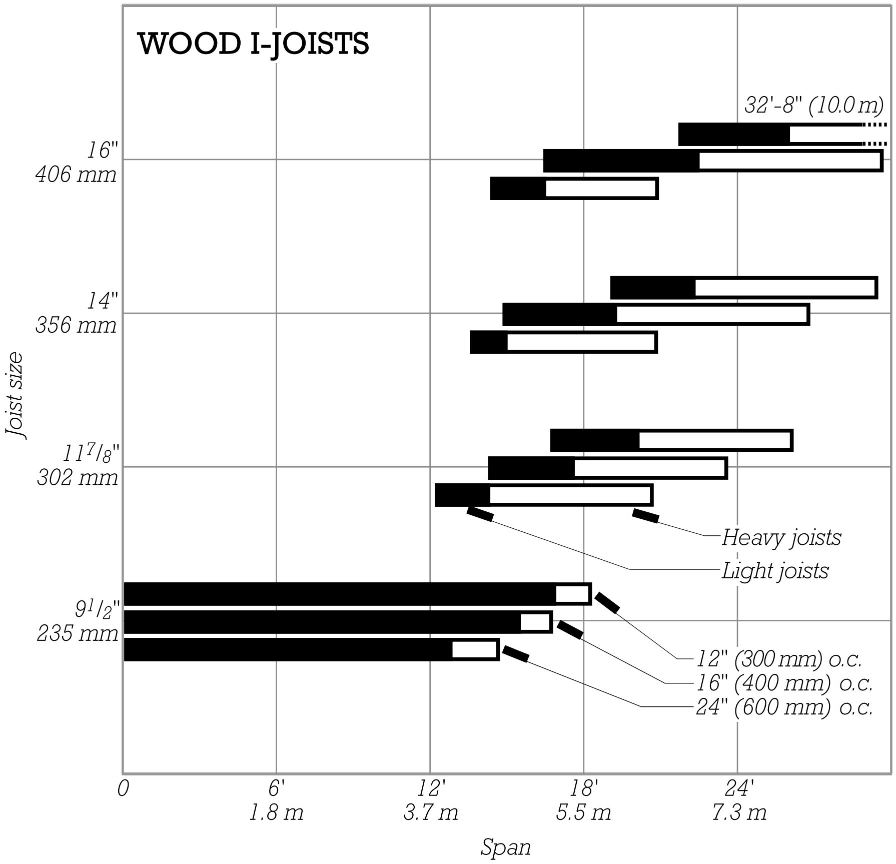




The top chart is for solid wood floor joists with residential floor loads. For joists supporting only attic loads, decrease the indicated size by one or two sizes. For larger loads, increase the indicated joist size by one or two sizes.

■ Read from the top, middle, or bottom bars for 12-in., 16-in., or 24-in. (300-, 400-, or 600-mm) joist spacings, respectively.

■ Read in the open bar areas for strong woods, such as Douglas Fir, Larch, Southern Pine, and Oak. Read in the solid bar areas for average-strength woods.



The bottom chart is for wood I-joists with residential floor loads. For joists supporting only attic loads, decrease the indicated size by one or two sizes. For larger loads, increase the indicated joist size by one or two sizes.

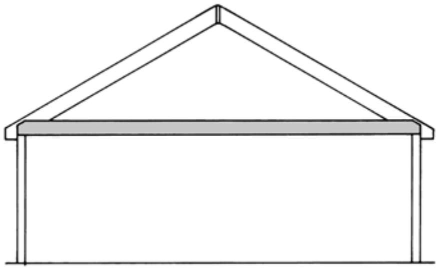
■ Read from the top, middle, or bottom bars for 12-in., 16-in., or 24-in. (300-, 400-, or 600-mm) joist spacings, respectively.

■ Read in the open bar areas for heavy- and medium-weight I-joists. Read in the solid bar areas for lightweight I-joists.

## ACTUAL SIZES OF ROOF RAFTERS

For the actual size of solid wood rafters, read from the following table. I-joists are listed in actual size.

| Nominal Size | Actual Size |
|---|---|
| 2 × 4 | 1½" × 3½" (38 × 89 mm) |
| 2 × 6 | 1½" × 5½" (38 × 140 mm) |
| 2 × 8 | 1½" × 7¼" (38 × 184 mm) |
| 2 ×10 | 1½" × 9¼" (38 × 235 mm) |

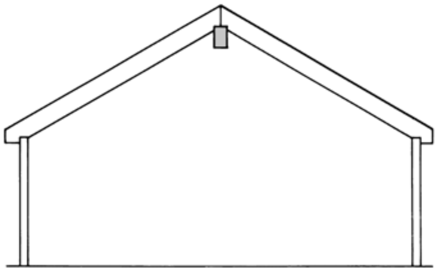


RAFTERS WITH RAFTER TIES

## TIES OR BEAMS SUPPORTING ROOF RAFTERS

Rafter ties connecting rafters at their bases may be sized either as floor joists, if they are intended to support habitable space, or as ceiling joists, if they are supporting attic loads only. See pages 60–61.

Structural ridge beams can eliminate the need for ties at the base of the rafters. See page 71 for sizing wood beams.

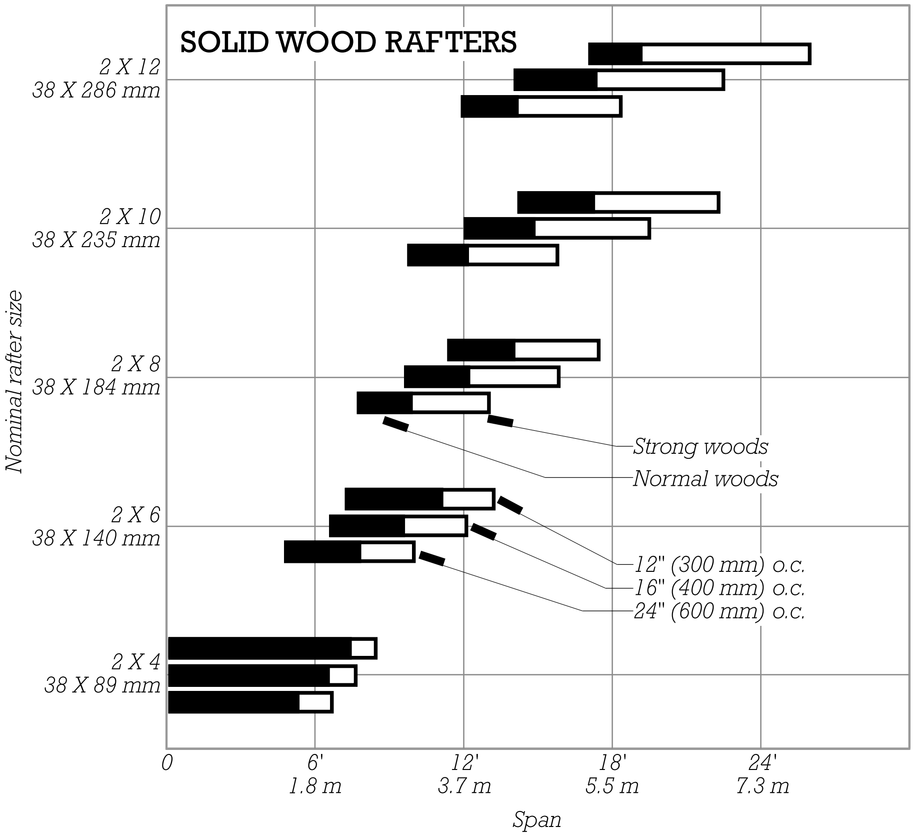


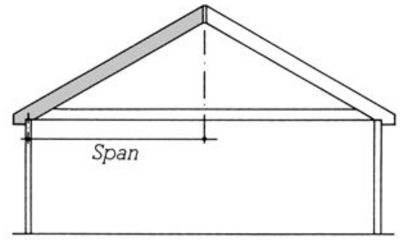
RAFTERS WITH RIDGE BEAM

## FIRE-RESISTANCE RATINGS FOR WOOD LIGHT FRAME RAFTERS

Wood roof rafters may be used in Ordinary Construction and Wood Light Frame Construction. A 1-hour fire-resistance rating can be achieved with two layers of ⅝-in. (16-mm) Type X gypsum board or its equivalent applied to the underside of the framing.

# WOOD ROOF RAFTERS



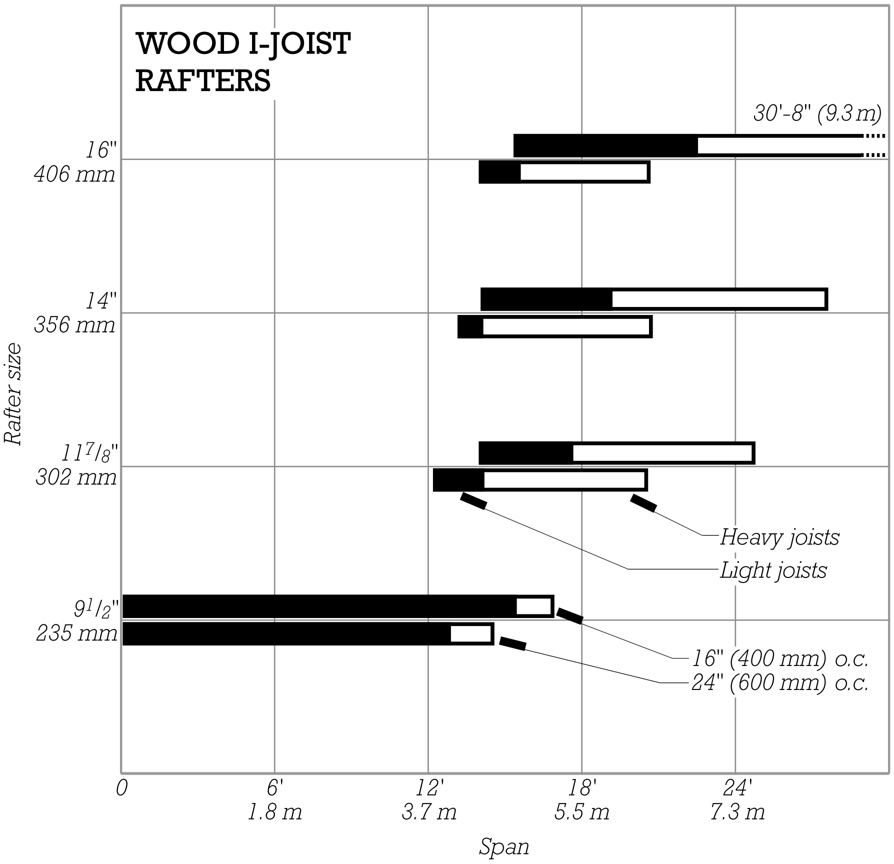


The top chart is for solid wood roof rafters with moderate snow loads (see page 32). For roofs without snow loads, decrease the indicated rafter size by one size. For roofs in heavy snow load areas, increase the rafter size by one or more sizes.

- ■ Read from the top, middle, or bottom bars for 12-in., 16-in., or 24-in. (300-, 400-, or 600-mm) rafter spacings, respectively.
- ■ Read in the open bar areas for strong woods, such as Douglas Fir, Larch, Southern Pine, and Oak. Read in the solid bar areas for average-strength woods.

The bottom chart is for I-joist roof rafters with moderate snow loads (see page 32). For roofs without snow loads, decrease the indicated rafter size by one size. For roofs in heavy snow load areas, increase the rafter size by one or more sizes.

- ■ Read from the top or bottom bars for 16-in. or 24-in. (400- or 600-mm) rafter spacings, respectively.
- ■ Read in the open bar areas for heavy- and medium-weight I-joists. Read in the solid bar areas for lightweight I-joists.



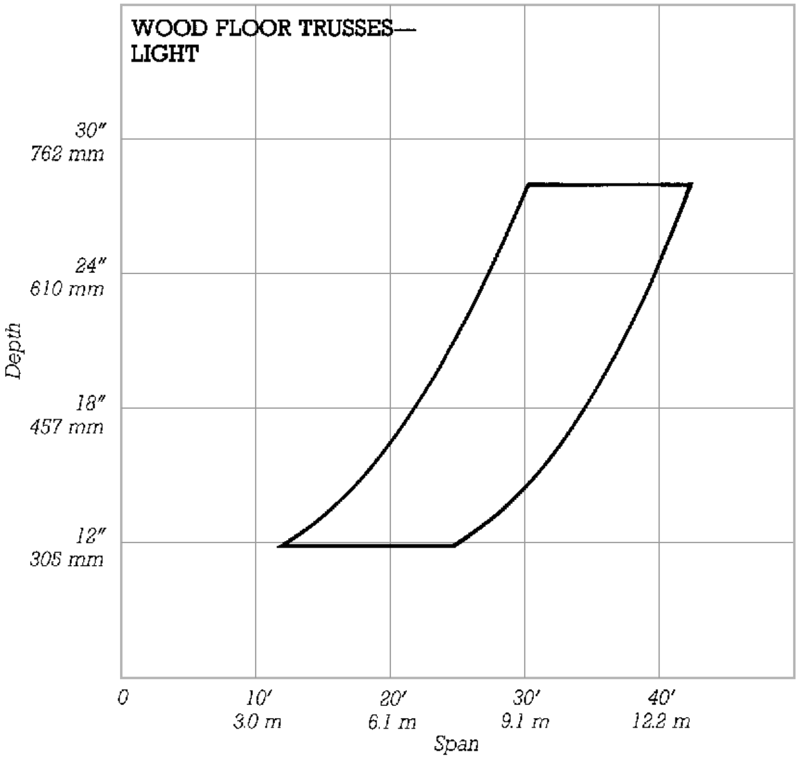
# WOOD FLOOR AND ROOF TRUSSES — LIGHT

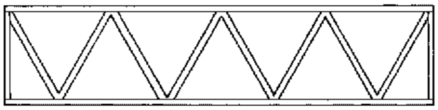
Light wood floor and roof trusses can easily be used in place of conventional wood joists and rafters in Platform Frame Construction. These prefabricated elements permit quicker erection in the field and greater clear spans. They require fewer interior loadbearing walls and permit easy running of electrical and mechanical services through the open spaces within the trusses.

## FIRE-RESISTANCE RATINGS FOR LIGHT WOOD TRUSSES

Light wood trusses may be used in Ordinary Construction and Wood Light Frame Construction. They can have a 1-hour fire-resistance rating when covered with nominal 1-in. (19-mm) subflooring and finish flooring and when the underside of the framing is finished with ⅝-in. (16-mm) Type X gypsum board or its equivalent. A 2-hour rating can be achieved with three layers of ⅝-in. (16-mm) Type X gypsum board and ⅝-in. (16-mm) furring channels.

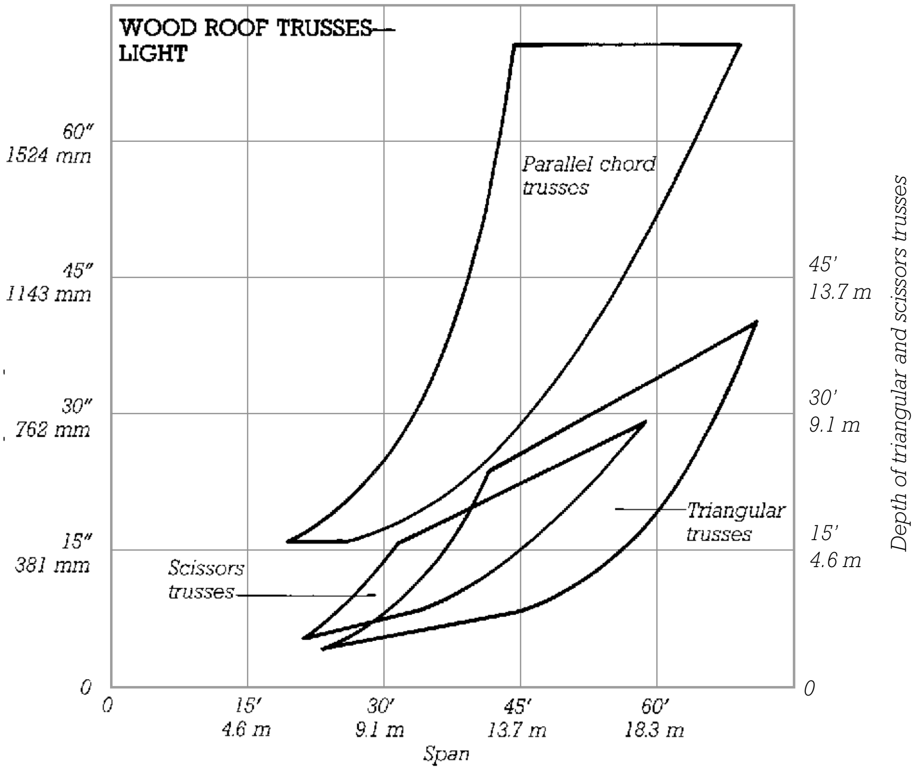
# WOOD FLOOR AND ROOF TRUSSES — LIGHT

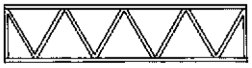




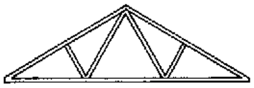
The top chart is for wood floor trusses constructed from light members up to 6 in. (140 mm) deep. For heavy loads, read toward the left in the indicated area. For light loads, read toward the right. For preliminary design, use depths in even 2-in. (50-mm) increments. Available sizes may vary with the manufacturer.

- ■ Typical truss spacing is 16 to 48 in. (400 to 1200 mm).

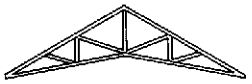




*Parallel chord truss*



*Triangular truss*



*Scissors truss*

The bottom chart is for wood roof trusses constructed from light members up to 6 in. (140 mm) deep. Read depths of parallel chord trusses from the left-hand scale and depths of other trusses from the right-hand scale. For heavy loads, read toward the left in the indicated areas. For light loads, read toward the right. Triangular or scissors trusses are commonly available with top chord slopes in whole number pitches from 2:12 to 7:12. Available sizes may vary with the manufacturer.

- ■ Typical truss spacing is 16 to 48 in. (400 to 1200 mm).

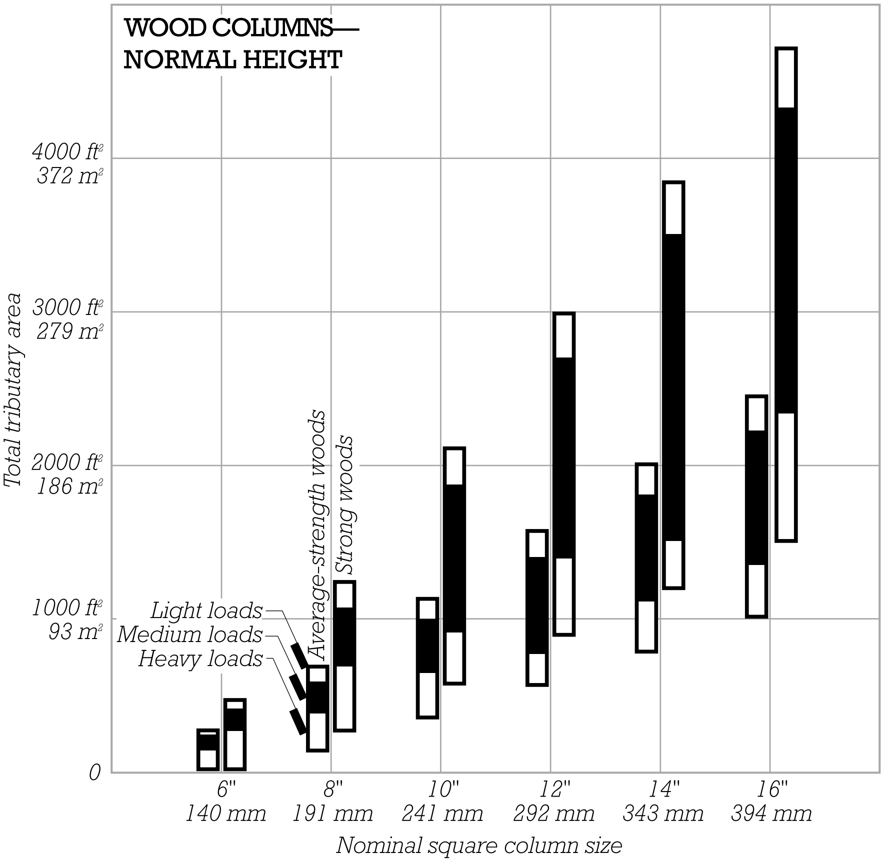
## WOOD STRENGTH

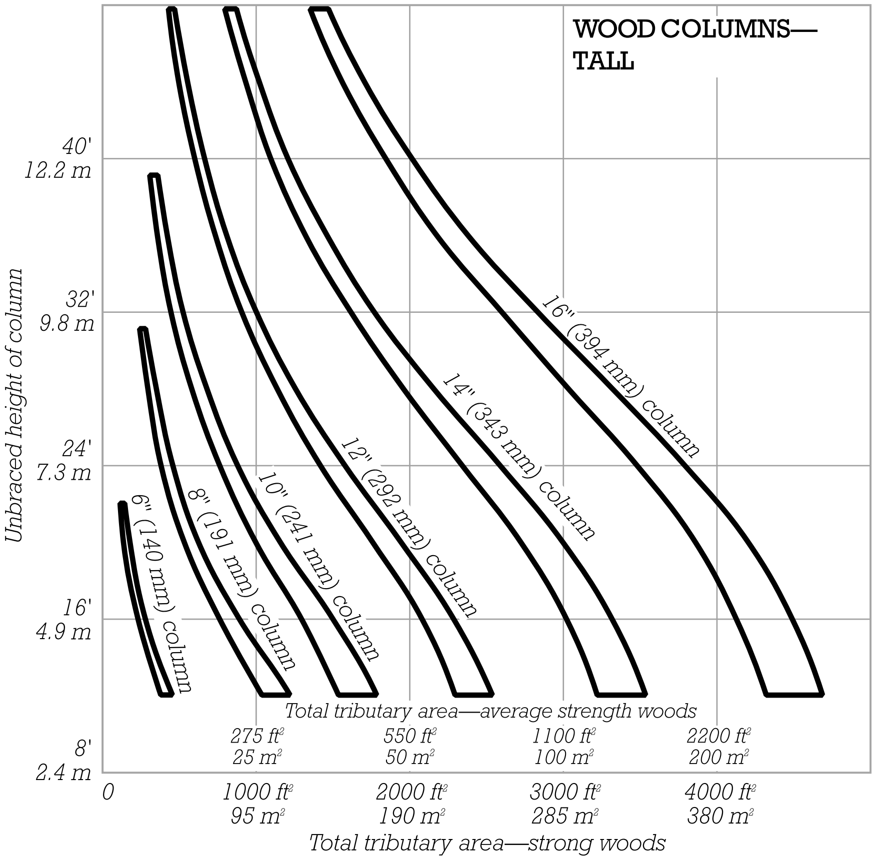
When reading the charts on the opposite page, examples of strong woods include Select Structural grades of Douglas Fir, Larch, Hemlock, and Southern Pine. Examples of average-strength woods include No. 2 grades of Hem-Fir and Spruce-Pine-Fir. For other species and grade combinations of intermediate strength, you may interpolate between the results charted for these two groups.

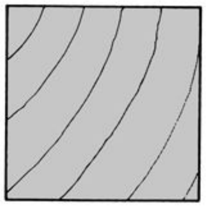
## FIRE-RESISTANCE RATINGS FOR WOOD COLUMNS

Wood columns may be used in any Combustible Construction type. To qualify as components of Heavy Timber Construction, wood columns supporting floor loads must have a nominal size of at least 8 × 8 in. (191 × 191 mm). Columns supporting roof and ceiling loads only may be as small as 6 × 8 in. (140 × 191 mm). Columns of lesser dimensions may be used in Ordinary and Wood Light Frame Construction.

# WOOD COLUMNS







The top chart is for solid wood columns up to 12 ft (3.7 m) in height. For each column size, read from the right-hand bar for strong woods or from the left-hand bar for average-strength woods. Read in the top open area for light loads, the middle solid area for medium loads, or the lower open area for heavy loads. *Total tributary area* is the summed area of the roof and all floors supported by the column.

■ For rectangular columns, select a column of area equal to the square size indicated.

■ Actual column size is ½ in. less than nominal English unit sizes. Metric equivalents are the actual size.

For columns taller than 12 ft (3.7 m), read from both charts on this page, using the larger column size indicated by either chart. *Unbraced height of column* is the vertical distance between floors or other supports that brace the column laterally against buckling.

■ For rectangular columns, read the lower chart using the smallest dimension of the column.

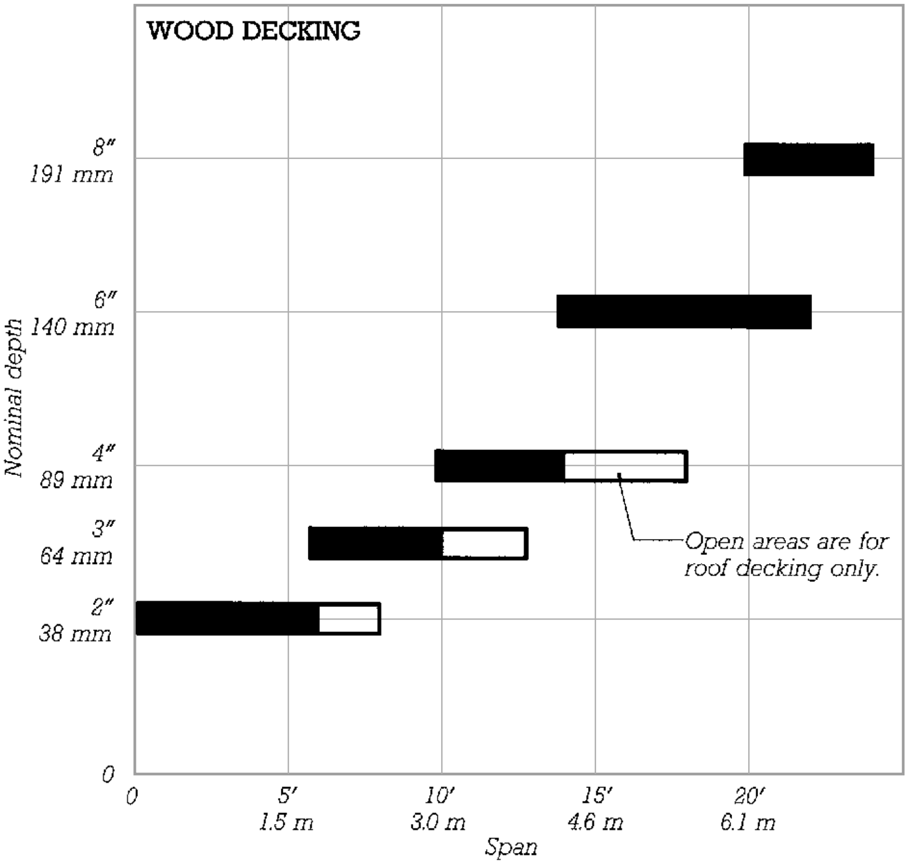
■ On the lower chart, read *Total tributary area* from the lower scale for strong woods or from the upper scale for average-strength woods.

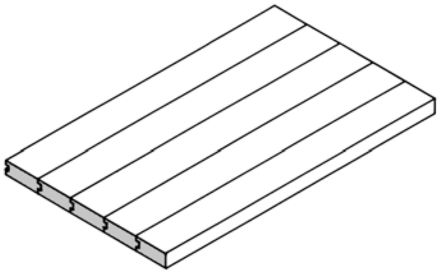
■ Read toward the right within the indicated curves for light loads and toward the left for medium loads. For heavy loads, read the total tributary area for light loads and then divide by half.

## FIRE-RESISTANCE RATINGS FOR WOOD DECKING

Wood decking may be used in any Combustible Construction type. To qualify for Heavy Timber Construction as defined by the building codes, wood floor decking must be at least 3 in. (64 mm) in nominal thickness, with minimum 1-in. nominal (19-mm) wood finish flooring laid over it at right angles. Roof decking for Heavy Timber Construction must be at least 2 in. (38 mm) in nominal thickness. Decking of lesser thickness may be used in Ordinary and Wood Light Frame Construction.

# WOOD DECKING



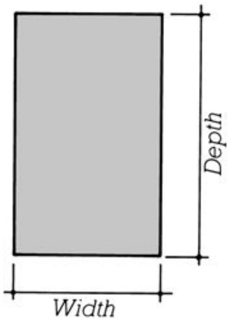


This chart is for solid or laminated wood decking. For light loads or strong woods, read toward the right in the indicated areas. For large loads or normal-strength woods, read toward the left.

- Strong woods include Douglas Fir, Larch, Southern Pine, and Oak.
- Decking comes in various nominal widths, 6 and 8 in. (150 and 200 mm) being the most common. Actual depth is ½ in. (13 mm) less than nominal.
- Allow approximately ¾ in. (19 mm) for the depth of finish flooring.

## SIZES OF SOLID WOOD BEAMS

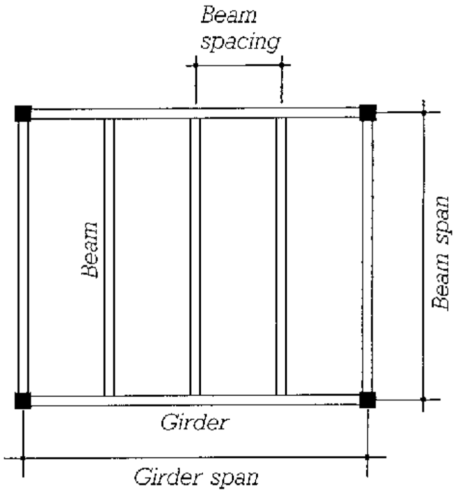
Actual depths of solid wood beams are ½ to ¾ in. less than nominal size. See the following table. Actual widths are ½ in. (13 mm) less than nominal.



| Nominal Depth | Actual Depth |
|---|---|
| 4" | 3½" (89 mm) |
| 6" | 5½" (140 mm) |
| 8", 10", 12" | ¾" (19 mm) less than nominal for beam widths of 2", 3", and 4", and<br>½" (13 mm) less than nominal for beam widths greater than 4" |
| 14" or greater | ½" (13 mm) less than nominal |

## FRAMING FOR HEAVY TIMBER CONSTRUCTION

A heavy timber framing system that uses both beams and girders allows for the greatest range of bay sizes and proportions. The beam spacing is determined by the allowable span of the floor or roof decking as tabulated on page 69. For preliminary design, limit beam and girder spans to a maximum of 20 ft (6 m) for solid wood decking or 24 ft (7.3 m) for laminated wood decking.

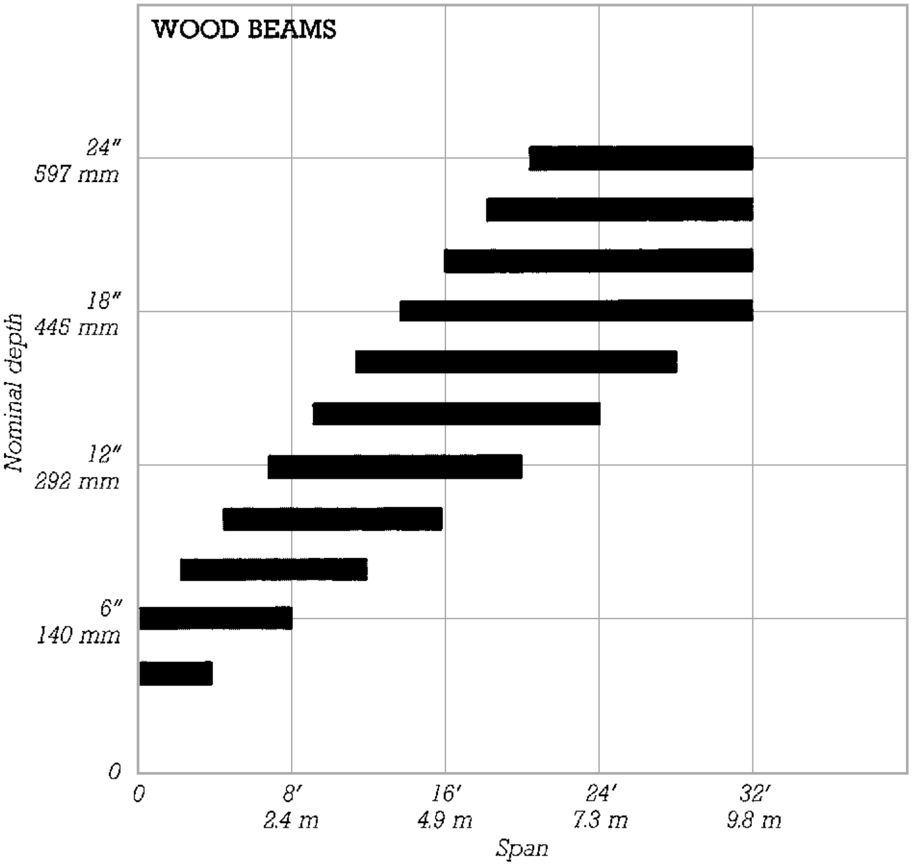


HEAVY TIMBER FLOOR FRAMING

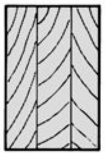
## FIRE-RESISTANCE RATINGS FOR WOOD BEAMS

Wood beams may be used in any Combustible Construction type. To qualify for Heavy Timber Construction, minimum size requirements for wood beams vary slightly between the model building codes. For preliminary design, wood beams supporting floors should be no smaller than nominal 6 × 10 (140 × 241 mm actual size), and those supporting roofs only should be no smaller than 4 × 6 (89 × 140 mm). Beams of lesser dimensions may be used in Ordinary and Wood Light Frame Construction. For more information on the minimum size requirements for wood beams used in Heavy Timber Construction in both model codes, see pages 382–383.

# WOOD BEAMS



**SOLID BEAM**



**BUILT-UP BEAM**

This chart is for solid and built-up wood beams. For girders, or for beams carrying large loads, read toward the left in the indicated areas. For light loads or strong woods, read toward the right. For typical beam conditions, read from the middle of the indicated areas.

- Strong woods include Douglas Fir, Larch, Southern Pine, and Oak.
- Practical widths for solid beams range from one-fourth of the depth of the beam to equal to the depth of the beam.
- A girder should be at least 2 in. (50 mm) deeper than the beams it supports.

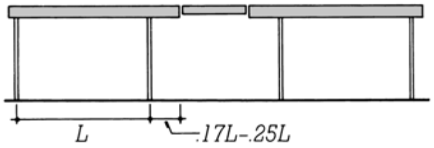
## SIZES OF GLUE-LAMINATED BEAMS

Glue-laminated beams are specified by their actual size. Depths are typically a multiple of 1½ in. (38 mm), the thickness of one lamination. For commonly available sizes, see the following table.

| **Width** | | **Depth** | |
|---|---|---|---|
| 3⅛" | (79 mm) | 3"–24" | (76–610 mm) |
| 5⅛" | (130 mm) | 4½"–36" | (114–914 mm) |
| 6¾" | (171 mm) | 6"–48" | (152–1219 mm) |
| 8¾" | (222 mm) | 9"–63" | (229–1600 mm) |
| 10¾" | (273 mm) | 10½"–75" | (267–1905 mm) |

## CONTINUOUS-SPAN GLUE-LAMINATED BEAMS

For greater structural efficiency, glue-laminated beams may be configured with continuous spans. For such beams, read toward the right in the indicated area on the chart on the facing page. Practical spans for continuous-span beam systems range from 25 to 65 ft (7.5 to 20.0 m).

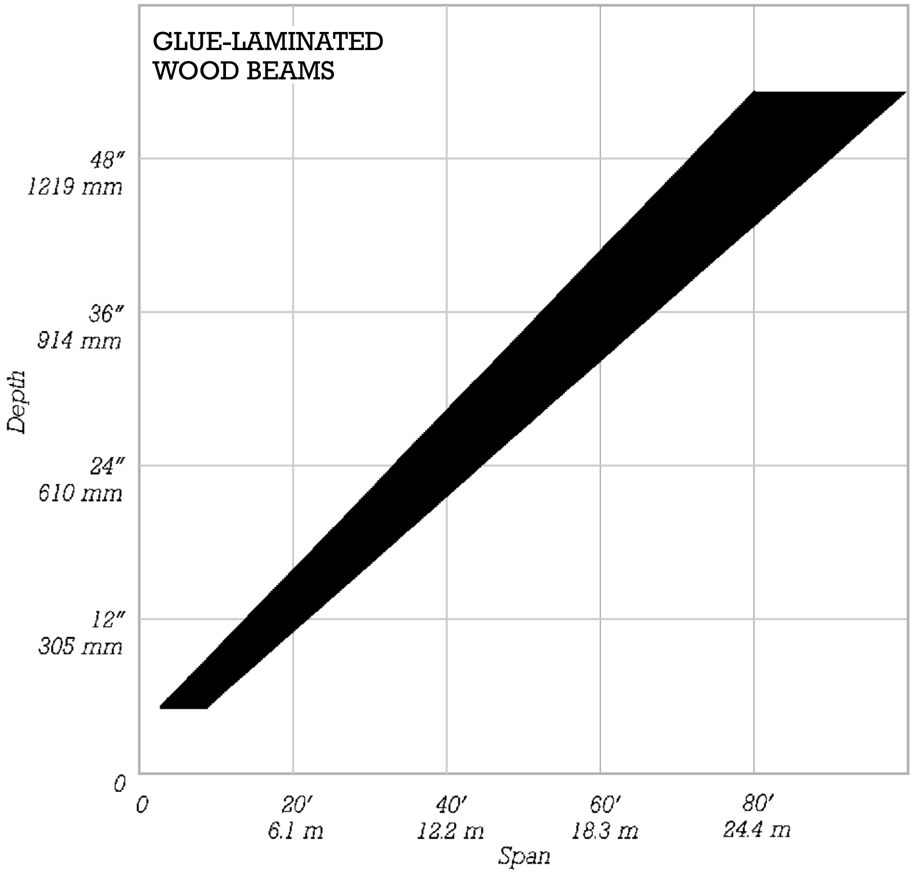


**CONTINUOUS-SPAN GLUE-LAMINATED BEAM**

## FIRE-RESISTANCE RATINGS FOR GLUE-LAMINATED WOOD BEAMS

Glue-laminated wood beams may be used in any Combustible Construction type. To qualify for Heavy Timber Construction, minimum size requirements for glue-laminated wood beams vary with each model building code. For preliminary design, beams supporting floors should be no smaller than 5 × 10½ in. (127 × 267 mm) actual size, and those supporting roofs only should be no smaller than 3 × 6⅞ in. (76 × 175 mm). Beams of lesser dimensions may be used in Ordinary and Wood Light Frame Construction. For more information on minimum size requirements for beams in Heavy Timber Construction in both model codes, see pages 382–383.

# GLUE-LAMINATED WOOD BEAMS



This chart is for glue-laminated beams.

- Normal spacings for glue-laminated beams range from 4 ft (1.2 m) for small beams supporting decking to 24 ft (7.3 m) for larger beams supporting joists or purlins.
- Typical widths for glue-laminated beams are one-fourth to one-seventh of the depth, rounded to the nearest standard width, as shown on the facing page.
- For girders, read depths from the extreme left-hand edge of the indicated area. A girder should be at least 1½ in. (38 mm) deeper than the beams it supports.

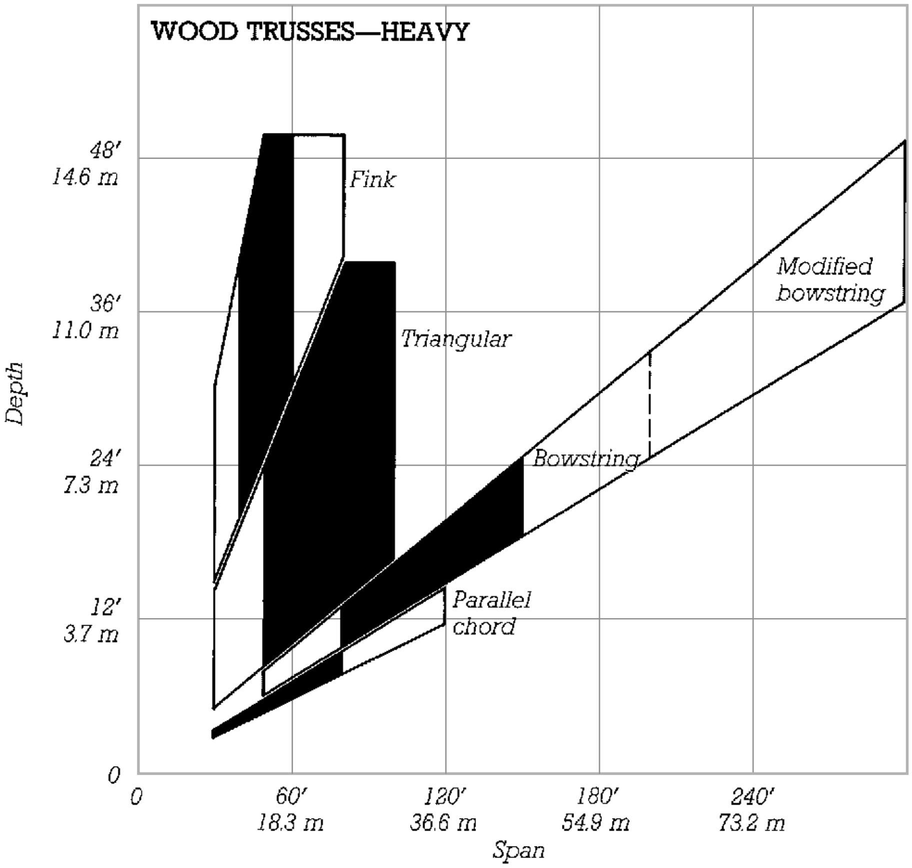
## SPACING OF HEAVY WOOD ROOF TRUSSES

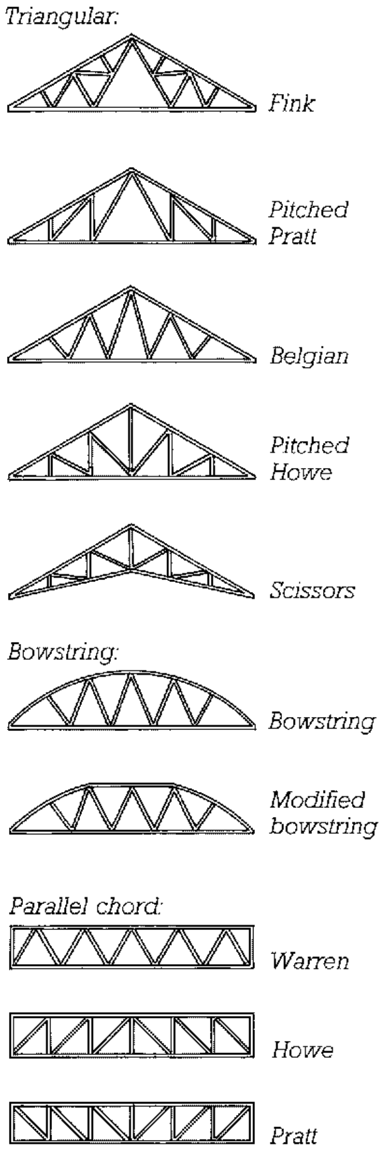
Roof trusses spaced no greater than 4 to 8 ft (1.2 to 2.4 m) require no additional joists or purlins. The maximum practical spacing of trusses with joists or purlins is approximately 20 ft (6.1 m).

## FIRE-RESISTANCE RATINGS FOR HEAVY WOOD TRUSSES

Heavy wood trusses may be used in any Combustible Construction type. To qualify for Heavy Timber Construction, minimum size requirements for wood trusses vary slightly between the model building codes. For preliminary design, trusses supporting floors should be made of members no smaller than nominal 8 × 8 (191 × 191 mm actual size), and those supporting roofs only should be made of members no smaller than 4 × 6 (89 × 140 mm). Trusses made of members of lesser dimensions may be used in Ordinary and Wood Light Frame Construction. For more information on the minimum size requirements for wood trusses used in Heavy Timber Construction in both model codes, see pages 382–383.

# WOOD TRUSSES — HEAVY





This chart is for wood trusses constructed from heavy members, a minimum of 4 × 6 in. (89 × 140 mm) in size.

■ The most economical span ranges for each truss type are indicated with the solid tone.

## DIMENSIONS FOR POINTED ARCHES

### LOW- TO MEDIUM-PITCH ARCHES (3:12 TO 8:12)

| Wall Height | Thickness of Arch | Depth of Base | Depth of Crown |
|---|---|---|---|
| 10'–18'<br>(3.0–5.5 m) | 3⅛", 5⅛", 6¾"<br>(79, 130, 171 mm) | 7½"–18" for short spans<br>(191–457 mm)<br>8"–30" for medium spans<br>(203–762 mm)<br>8½"–35" for long spans<br>(216–889 mm) | 7½"–27"<br>(191–686 mm) |

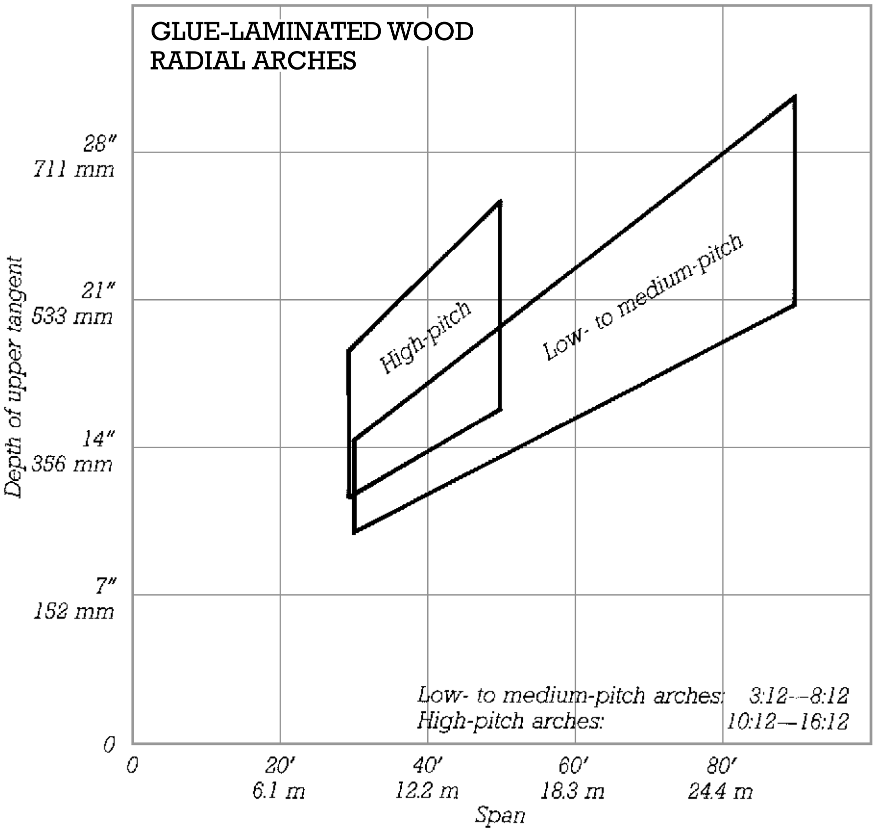
### HIGH-PITCH ARCHES (10:12 TO 16:12)

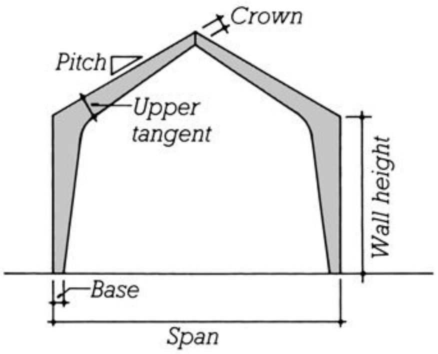
| Wall Height | Thickness of Arch | Depth of Base | Depth of Crown |
|---|---|---|---|
| 8'–12'<br>(2.4–3.7 m) | 5⅛"<br>(130 mm) | 7½" for short spans<br>(191 mm)<br>7¾" for medium spans<br>(197 mm)<br>9½"–10" for long spans<br>(241–254 mm) | 7¾"–24½"<br>(197–622 mm) |

## FIRE-RESISTANCE RATINGS FOR GLUE-LAMINATED ARCHES

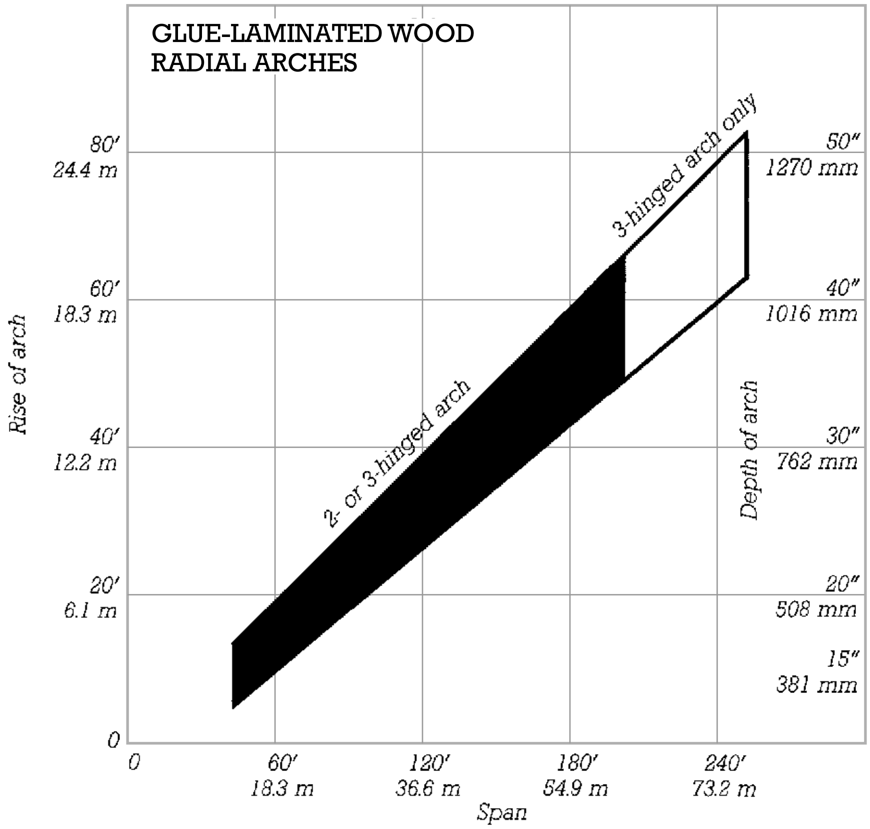
Glue-laminated wood arches may be used in any Combustible Construction type. To qualify for Heavy Timber Construction, minimum size requirements for such arches vary slightly between the model building codes. For preliminary design, arches supporting floors should be no smaller than 6¾ × 8¼ in. (171 × 210 mm) actual size, and those supporting roofs only should be no smaller than 5 × 8¼ in. (127 × 210 mm). Arches of lesser dimensions may be used in Ordinary and Wood Light Frame Construction. For more information on the minimum size requirements for glue-laminated wood arches used in Heavy Timber Construction in both model codes, see pages 382–383.

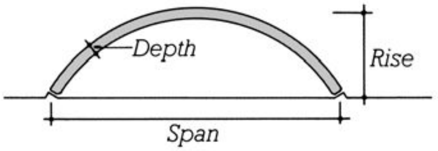
# GLUE-LAMINATED WOOD ARCHES



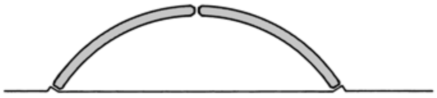


The top chart is for glue-laminated pointed arches. For low pitches, high loads, and high side walls, read toward the top in the indicated areas. For high pitches, low loads, and low side walls, read toward the bottom.





**TWO-HINGE RADIAL ARCH**



**THREE-HINGE RADIAL ARCH**

The bottom chart is for glue-laminated radial arches. Read the rise of the arch from the left-hand scale and the depth of the arch from the right-hand scale.

- ■ The thickness of a radial arch should be at least one-fifth of its depth.

# MASONRY STRUCTURAL SYSTEMS

Masonry construction rarely forms a complete building system by itself. Nonbearing masonry walls can be used as infill between framing elements or as a veneer applied over other structural systems. Loadbearing masonry walls and columns can be combined with various spanning elements to form complete structural systems. With proper reinforcing, masonry walls can also be designed to resist lateral loads.

Masonry walls may be constructed in a variety of ways. Use the following guidelines for preliminary design:

- Single-wythe walls are generally limited to nonbearing applications or as a veneer over other wall systems.
- Cavity wall construction is a preferred choice for exterior walls because of its superior resistance to water penetration and its improved thermal performance.
- Concrete masonry construction is generally more economical than brick because of the lower materials costs and the reduced labor required to lay the larger concrete units.
- Loadbearing masonry walls and columns must be steel reinforced in all but the smallest structures.

Since masonry construction takes place on-site and utilizes elements of small size, it is well suited for use in the construction of buildings of irregular form. Nevertheless, it is advantageous to build with modular dimensions to minimize the need for partial units. Wherever possible, use a module of one-half the nominal length of a masonry unit in plan and the height of one brick or concrete unit course in elevation.

## MASONRY AND WOOD CONSTRUCTION

Masonry can form the exterior, and sometimes interior, loadbearing walls for either Wood Light Frame Construction or Heavy Timber Construction, systems traditionally named *Ordinary Construction* and *Mill Construction*, respectively. Both of these systems have higher fire-resistance ratings than all-wood construction and are permitted for use in larger and taller buildings. For more information on the fire resistance of these systems and the building types for which their use is permitted, see pages 382–383. For sizing the wood elements of Ordinary or Heavy Timber Construction, see the appropriate pages under Wood Structural Systems beginning on page 57.

## MASONRY AND STEEL CONSTRUCTION

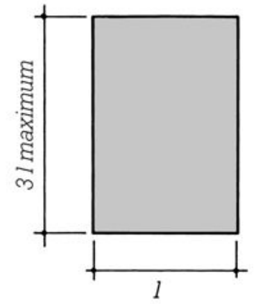
Open-web joists are the steel spanning elements most commonly used with loadbearing masonry construction because of the relatively small concentrated loads produced by these lightweight, closely spaced elements. Where steel beams and girders bear upon masonry walls, pilasters or extra reinforcing may be required at points of support. For economy and strength, interior columns in such systems are typically structural steel rather than masonry. See page 91 and the appropriate following pages for information on steel construction.

## MASONRY AND CONCRETE CONSTRUCTION

The sitecast and precast concrete spanning elements most commonly used with loadbearing masonry walls are shorter span slabs without ribs or beams. These systems are often highly economical due to the minimal floor depths associated with these spanning elements, the absence of any requirement for added fire-resistive finishes, and the acoustical and energy performance of these high-mass materials. See page 107 for information on sitecast concrete construction and page 125 for information on precast concrete construction.

## MASONRY STRENGTH

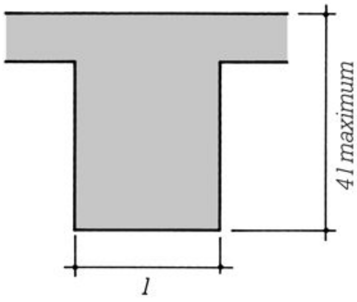
The strength and cost of brick masonry construction increase as stronger brick, steel reinforcing, and mortar mixes are used in its construction. When reading the top chart on the facing page, begin by assuming low-strength masonry and read from the lower set of bars. If the wall sizes yielded by this result are impractically large, then consider using higher-strength masonry, reading from the upper set of bars or interpolating between the two sets.



**RECTANGULAR COLUMNS**

## BRICK MASONRY COLUMN SIZES

For lightly loaded structures, the minimum size for reinforced brick masonry columns is 8 in. (200 mm) nominally on each side. For other conditions, use columns 12 in. (300 mm) square or larger. For rectangular columns, the wider side should be no more than three times the width of the narrower side. For pilasters (columns part of walls), the wider side should not exceed four times the width of the shorter side. For maximum economy, size brick masonry columns in increments of 4 in. (100 mm).

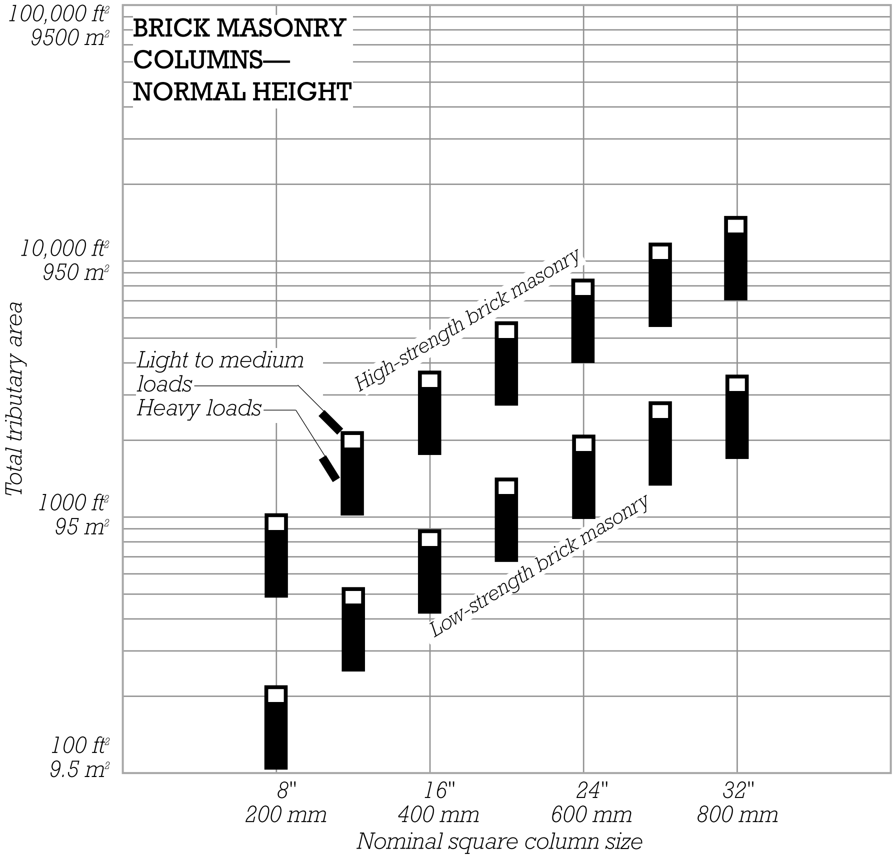


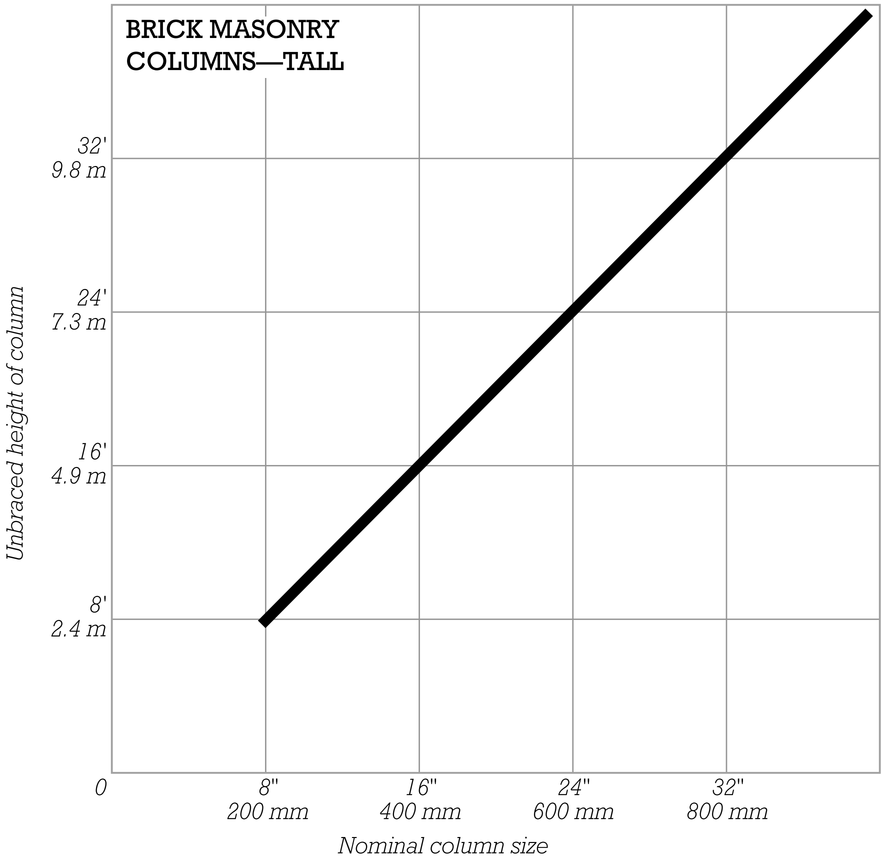
**RECTANGULAR PILASTERS**

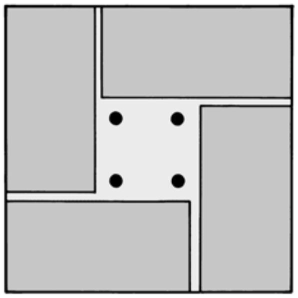
## FIRE-RESISTANCE RATINGS FOR BRICK MASONRY COLUMNS

Brick masonry construction may be used in both Combustible and Noncombustible Construction. The fire resistance of brick masonry construction varies with the type of brick unit. For preliminary design, assume that a 1- to 2-hour fire-resistance rating can be achieved with an 8-in. (200-mm) square column and a 3- to 4-hour or greater rating can be achieved with a 10- to 12-in. (250- to 300-mm) column.

# BRICK MASONRY COLUMNS







The top chart is for reinforced brick masonry columns up to 12 ft (3.7 m) tall between floors. For high-compressive-strength masonry, read from the upper set of bars. For low-strength masonry, read from the lower set. For light to medium loads, read in the upper open areas of each bar; for heavy loads, read in the lower solid areas. *Total tributary area* is the summed area of the roof and all floors supported by the column.

■ For rectangular columns, select a column of area equal to the square size indicated.

■ Actual column size is ⅜ in. (10 mm) less than nominal size.

For columns taller than 12 ft (3.7 m), read from both charts on this page, using the larger size indicated by either chart. *Unbraced height of column* is the vertical distance between floors or other supports that brace the column laterally against buckling.

■ For rectangular columns, read the chart's nominal column size using the lesser dimension of the column.

## MASONRY STRENGTH

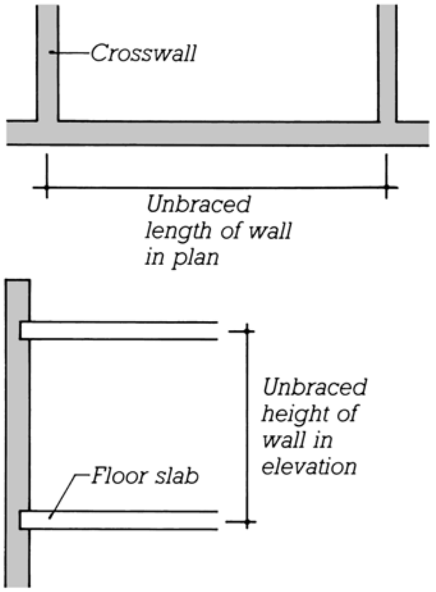
The strength and cost of brick masonry construction increase as stronger brick, steel reinforcing, and mortar mixes are used in its construction. When reading the top chart on the facing page, begin by assuming low-strength masonry and read from the lower set of curves. If the wall sizes yielded by this result are impractically large, then consider using higher-strength masonry, reading from the upper set of curves or interpolating between the two sets.

## MINIMUM WIDTHS OF WALLS

Reinforced brick masonry walls 6 in. (150 mm) wide should be used for one-story structures only. Use walls 8 in. (200 mm) or wider for multistory structures.

## MAXIMUM UNBRACED LENGTH OF WALL

Use the bottom chart on the facing page to determine the maximum permissible unbraced length of wall in plan in addition to its maximum permissible height. Masonry walls should be braced by crosswalls spaced at distances not exceeding those indicated on the chart. If the proposed crosswall spacing in your design is too great, either thicken the wall or add pilasters at intermediate spacing (see pages 80–81 for the sizing of pilasters).



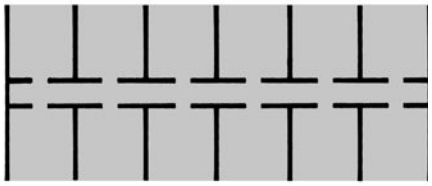
**UNBRACED HEIGHT OR LENGTH OF MASONRY WALLS**

## DESIGNING WITH MASONRY BEARING WALLS

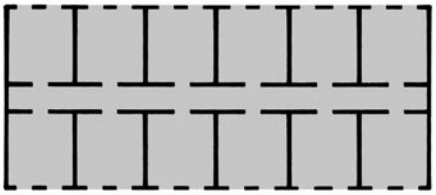
Reinforced brick masonry walls may be used in structures up to approximately 20 stories in height. In high-rise structures, the cellular arrangements of the bearing walls make this system best suited to apartment buildings, hotels, dormitories, and other residential occupancies that require relatively small, repetitively arranged spaces.

For structures up to approximately six stories in height, interior crosswalls and corridor walls should be sufficient to provide the needed lateral bracing for the structure. This permits exterior walls to remain relatively open in design. At greater heights, lateral stability requirements increasingly dictate a more complete cellular configuration of walls. In this case, the sizes of openings in the exterior walls will become increasingly restricted.

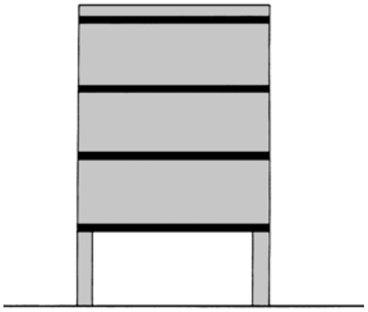
Loadbearing walls should be aligned consistently from floor to floor and should be continuous from the roof to the building foundation. Where it is desirable to create a larger space on a lower floor, it may be possible to design one or more of the walls above to act as deep beams spanning between columns. Such wall beams may span as much as 20 to 30 ft (6 to 9 m).



**LOW-RISE BEARING WALL CONFIGURATION (*shown in plan*)**



**HIGH-RISE BEARING WALL CONFIGURATION (*shown in plan*)**

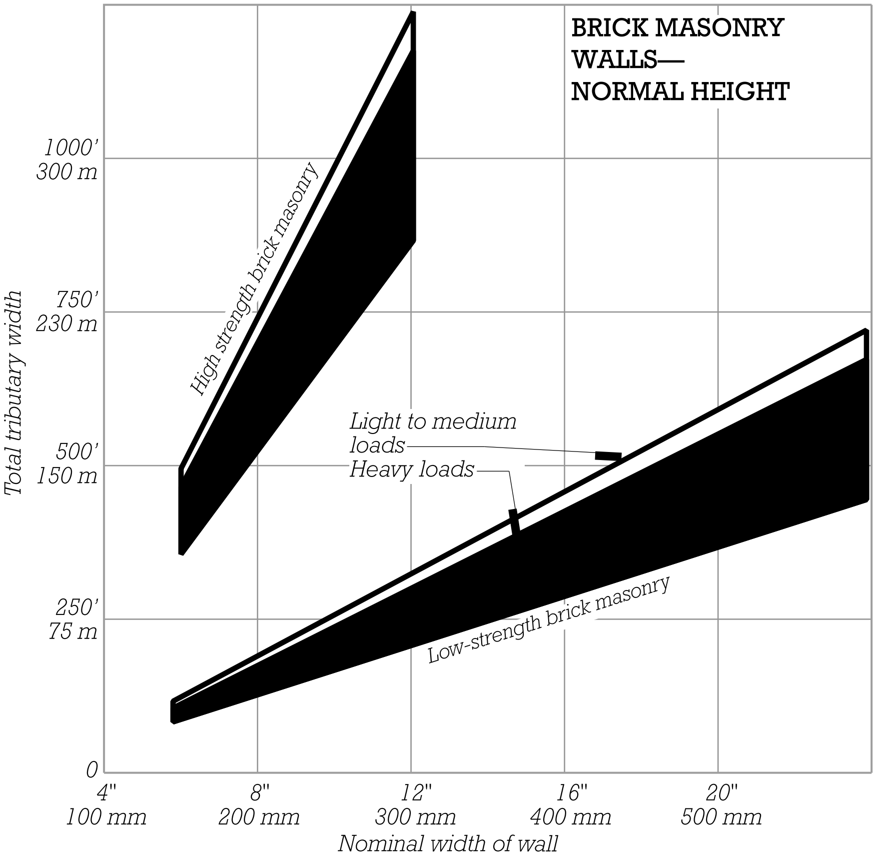


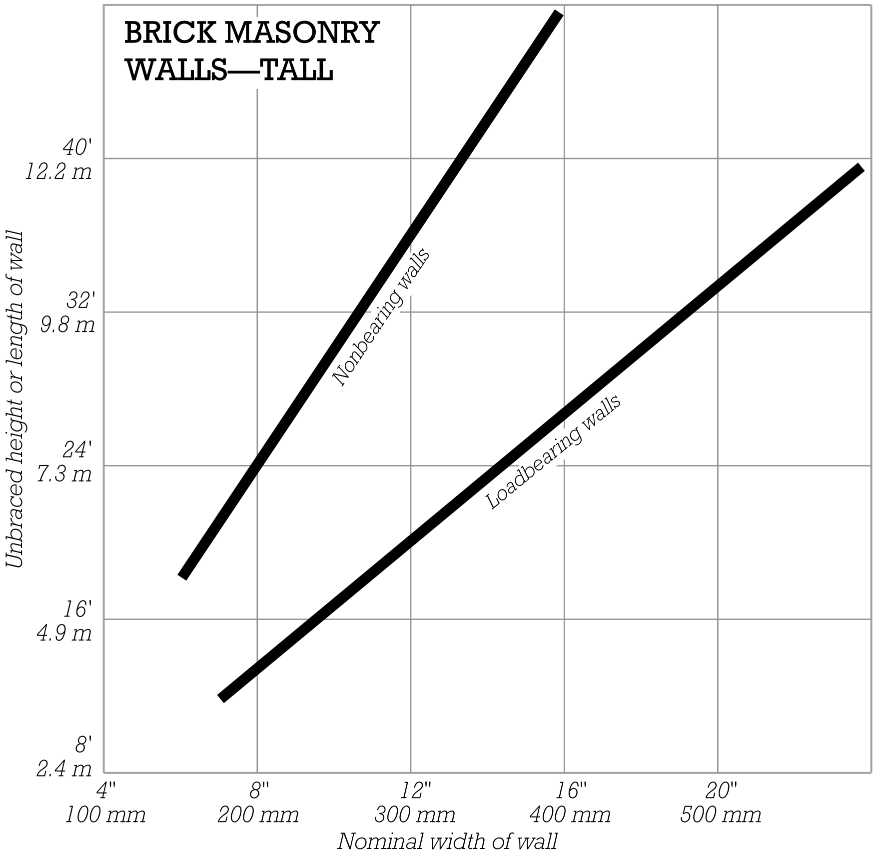
***Bearing walls may act as deep beams to span across openings below, as shown in this schematic cross section.***

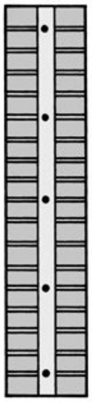
## FIRE-RESISTANCE RATINGS FOR BRICK MASONRY WALLS

Brick masonry construction may be used in both Combustible and Noncombustible Construction. The fire resistance of brick masonry construction varies with the type of brick unit. For preliminary design, assume that a 1-hour fire-resistance rating can be achieved with a 4-in. (100-mm)-thick wall, a 2-hour rating with a 6-in. (150-mm) wall, and a 3- to 4-hour rating with an 8-in. (200-mm) wall.

# BRICK MASONRY WALLS







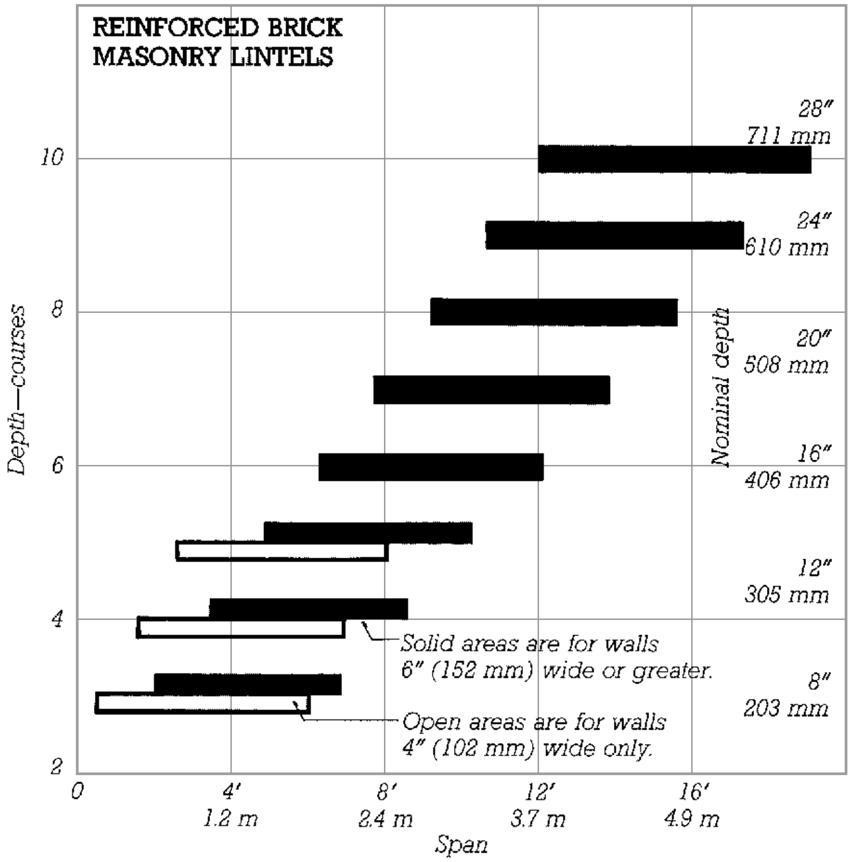
The top chart is for reinforced brick masonry walls up to 12 ft (3.7 m) tall between floors. For high-compressive-strength masonry, read from the upper set of curves. For low-strength masonry, read from the lower set. For light loads, read in the upper open areas of each curve; for medium to heavy loads, read in the lower solid areas. *Total tributary width* is one-half the span of one floor supported by the wall multiplied by the number of floors and the roof above.

- For cavity walls, use only the net width of the structural wythe when reading the charts on this page.

- Actual width of a wall is ⅜ in. (10 mm) less than the nominal size.

For walls greater than 12 ft (3.7 m) in height or unbraced length, read from both charts on this page, using the larger size indicated by either chart. Read along the *Loadbearing walls* curve for walls bearing gravity loads or wind loads. Read along the *Nonloadbearing walls* curve for interior nonloadbearing partitions. *Unbraced height of wall* is the vertical distance between floors. *Unbraced length of wall* is the horizontal distance between crosswalls or pilasters. See the facing page for more information on unbraced wall length.

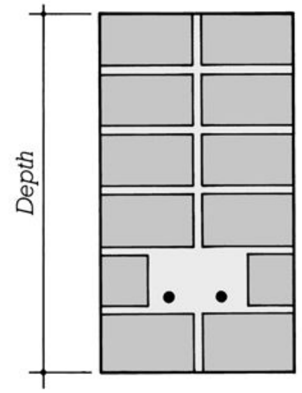
# BRICK MASONRY LINTELS



REINFORCED BRICK MASONRY LINTELS

Solid areas are for walls 6″ (152 mm) wide or greater.

Open areas are for walls 4″ (102 mm) wide only.



The chart at the left is for steel-reinforced brick masonry lintels. For lintels carrying only wall loads, read toward the right in the indicated areas. For lintels carrying floor loads or other superimposed loads, read toward the left. For most applications, lintel depths of four to seven courses are sufficient.

■ Depths for this chart are based on modular brick coursing where three courses = 8 in. (200 mm). For other coursing dimensions, read depths in inches from the right-hand scale and round up to a whole course height.

■ Actual depth is the thickness of one mortar joint less than the nominal depth (approximately ½ in., or 13 mm).

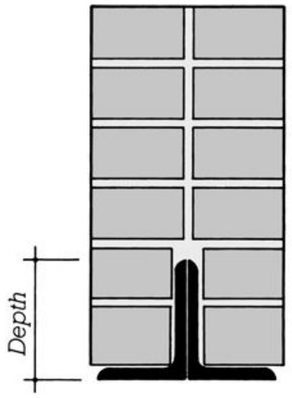
## STEEL ANGLE LINTELS

The following chart is for steel angle lintels carrying wall loads only. Heavier structural shapes, such as channels or wide-flange sections combined with plates, may be used where longer spans or greater load capacities are required.

| **Depth of Angle** | **Maximum Span** |
|---|---|
| 3" (76 mm) | 5' (1.5 m) |
| 4" (102 mm) | 6' (1.8 m) |
| 5" (127 mm) | 7' (2.1 m) |
| 6" (152 mm) | 8' (2.4 m) |

## FIRE-RESISTANCE RATINGS FOR BRICK MASONRY LINTELS

Brick masonry lintels may be used in both Combustible and Noncombustible Construction. Lintels not less than 8 in. (200 mm) in nominal dimension may be assumed to have a fire-resistance rating of 2 hours.



**STEEL ANGLE LINTEL**

# BRICK MASONRY ARCHES

## MINOR BRICK ARCHES

For spans of up to 6 to 8 ft (1.8 to 2.4 m), almost any shape of arch will work, particularly when the arch is embedded in a wall. Depths of minor brick arches typically range from 4 to 16 in. (100 to 400 mm). Thicknesses should be at least 4 to 8 in. (100 to 200 mm). Concentrated loads bearing directly on minor arches, especially jack arches, should be avoided.

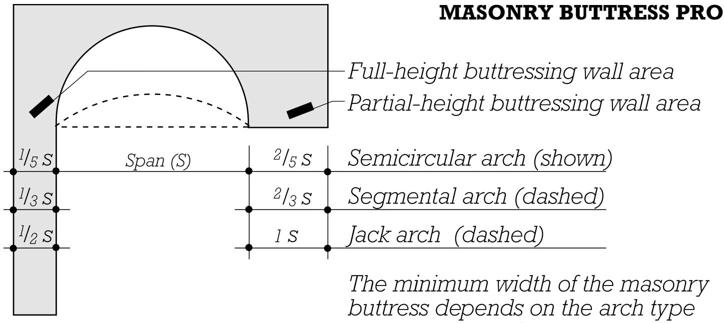
Segmental arches are most efficient when the rise of the arch is between 0.08 and 0.15 times the span of the arch. See the following table for proportioning jack arches. Note that camber is not a structural requirement in a jack arch but, rather, is used to avoid the appearance of sag. As an example of using the table, a jack arch 12 in. deep spanning 6 ft should have a ¾-in. camber (⅛" × 6') and 9-in. skewback (½" × 6' × 12"/4") at each end.

**JACK ARCH PROPORTIONS**

| Maximum Span Without Lintel | Camber | Depth | Skewback |
|---|---|---|---|
| 6' (1800 mm) | ⅛" per foot of span (1:100) | 8" (200 mm) minimum | ½" per foot of span for every 4" of arch depth (40 mm per meter of span for every 100 mm of arch depth) |

The horizontal thrust produced by an arch must be resisted at its supports. This resistance can be provided by a tie rod acting in tension, the opposing thrust of an adjacent arch, or the buttressing action of an adjacent masonry wall area. When relying on abutting masonry, the minimum width of the masonry area depends on the type of arch and the vertical height of the abutting masonry. See the following diagram.

**MASONRY BUTTRESS PROPORTIONS**



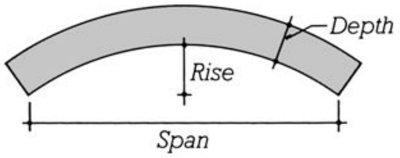
*The minimum width of the masonry buttress depends on the arch type and the height of the buttress.*

## MAJOR BRICK ARCHES

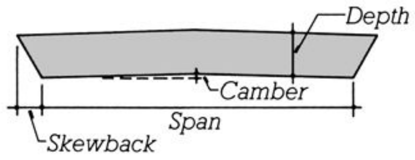
Major brick arches can span as far as approximately 250 ft (75 m). Parabolic shapes are recommended for long-span arches. Practical proportions for the rise of major arches range from approximately 0.2 to 0.6 times the span. For maximum efficiency, this proportion should not exceed 0.25.

## FIRE-RESISTANCE RATINGS FOR BRICK MASONRY ARCHES

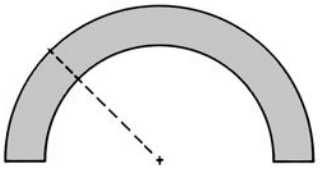
Brick masonry arches may be used in both Combustible and Noncombustible Construction. Arches that are not less than 8 in. (200 mm in nominal dimension can be assumed to have a fire-resistance rating of 2 hours.



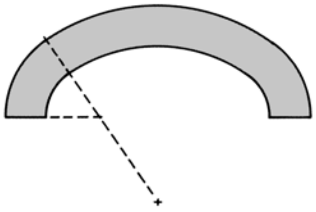
**SEGMENTAL ARCH**



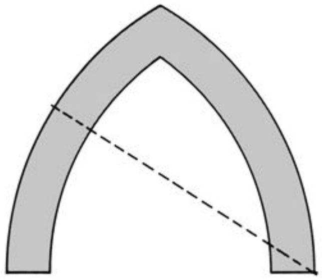
**JACK ARCH**



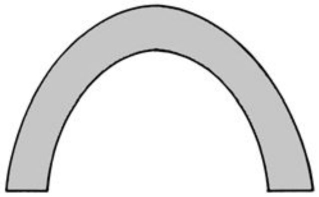
**SEMICIRCULAR ARCH**



**MULTICENTERED ARCH**



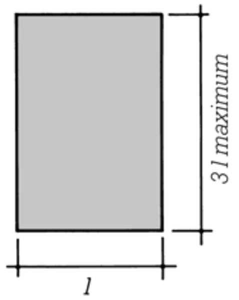
**POINTED ARCH**



**PARABOLIC ARCH**

## MASONRY STRENGTH

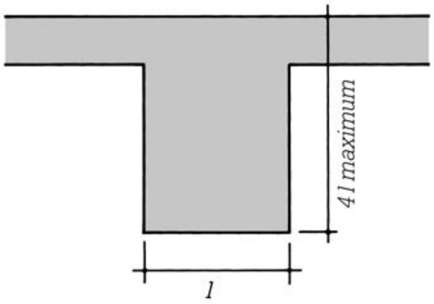
The strength and cost of concrete masonry construction increase as stronger concrete units, steel reinforcing, and mortar mixes are used in its construction. When reading the top chart on the facing page, begin by assuming low-strength masonry and read from the lower set of bars. If the column sizes yielded by this result are impractically large, then consider using higher-strength masonry, reading from the upper set of bars or interpolating between the two sets.



RECTANGULAR COLUMNS

## CONCRETE MASONRY COLUMN SIZES

For lightly loaded structures, the minimum size for reinforced concrete masonry columns is 8 in. (200 mm). For other conditions, use columns 12 in. (300 mm) square or larger. For rectangular columns, the wider side should be no more than three times the width of the narrower side. For pilasters (columns part of walls), the wider side should not exceed four times the width of the shorter side. For maximum economy, size concrete masonry columns in increments of 4 in. (100 mm).

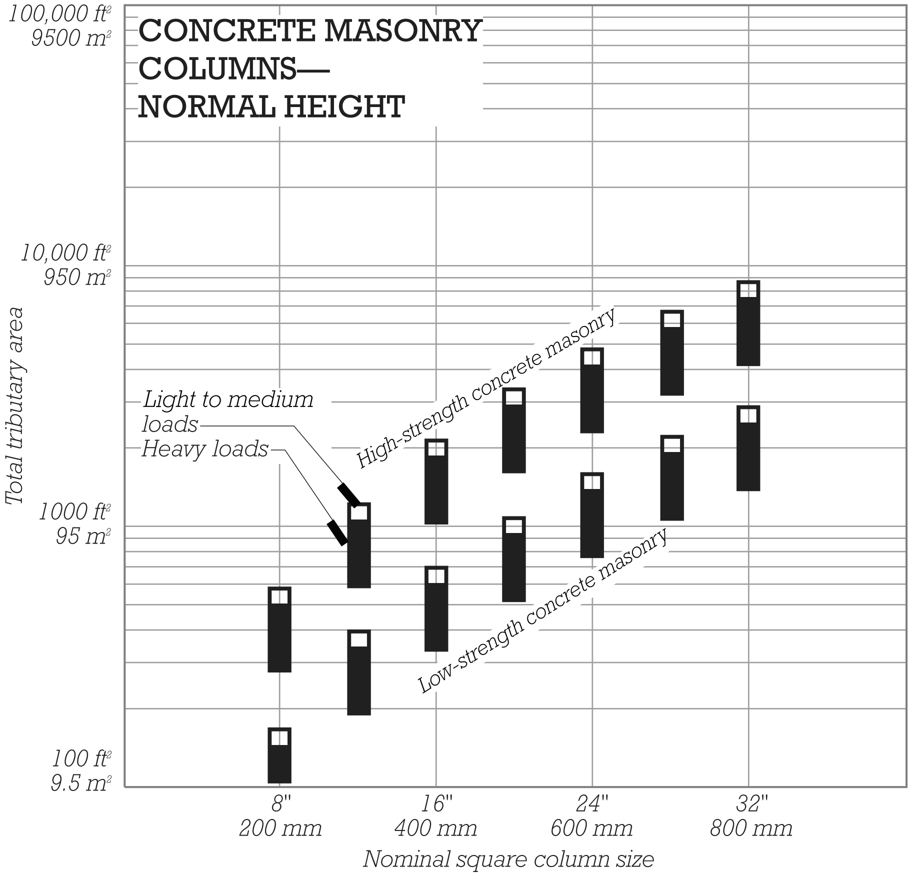


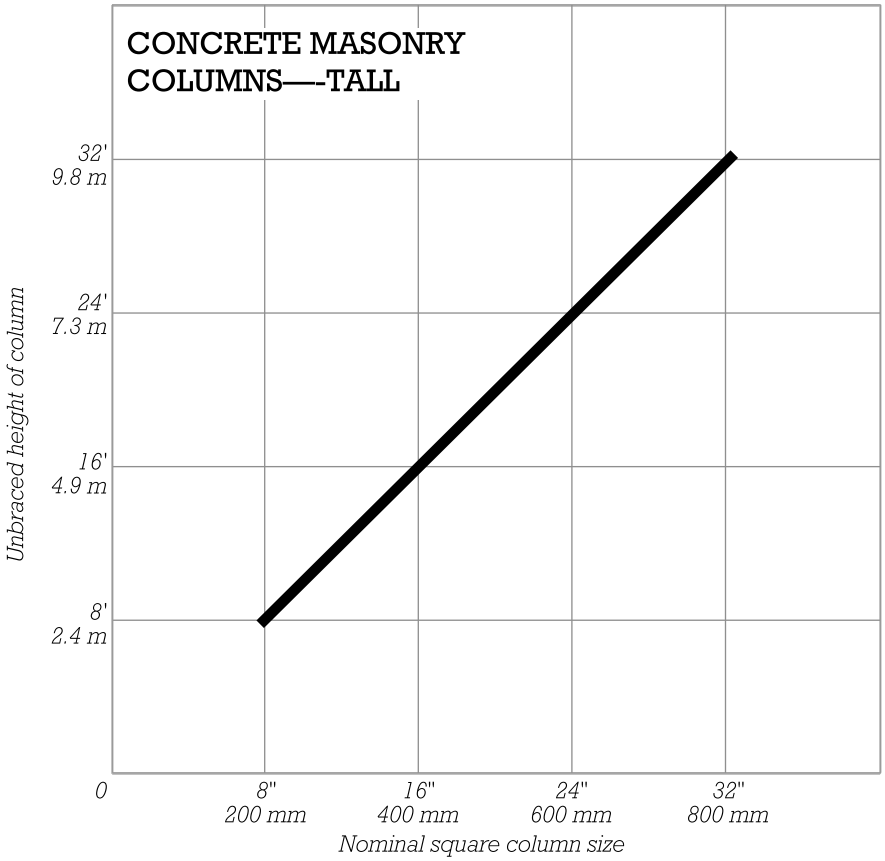
RECTANGULAR PILASTERS

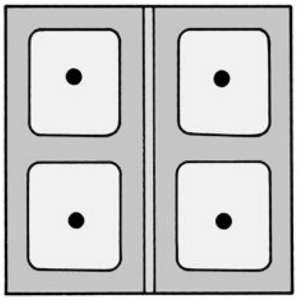
## FIRE-RESISTANCE RATINGS FOR CONCRETE MASONRY COLUMNS

Concrete masonry may be used in Combustible and Noncombustible Construction. The fire resistance of concrete masonry construction varies with the type of concrete units. For preliminary design, concrete columns with a least dimension of 8 in. (200 mm) may be assumed to have a fire-resistance rating of 1 hour, and those with least dimensions of 10 in. (250 mm), 12 in. (300 mm), and 14 in. (350 mm) to have fire-resistance ratings of 2, 3, and 4 hours, respectively.

# CONCRETE MASONRY COLUMNS







The top chart is for concrete masonry columns up to 12 ft (3.7 m) tall between floors. For high-compressive-strength masonry, read from the upper set of bars. For low-strength masonry, read from the lower set. For light to medium loads, read in the upper open areas of each bar; for heavy loads, read in the lower solid areas. *Total tributary area* is the summed area of the roof and all floors supported by the column.

- For rectangular columns, select a column of area equal to the square size indicated.
- Actual column size is ⅜ in. (10 mm) less than nominal size.

For columns taller than 12 ft (3.7 m), read from both charts on this page, using the larger size indicated by either chart. *Unbraced height of column* is the vertical distance between floors or other supports that brace the column laterally against buckling.

- For rectangular columns, read *Nominal square column size* using the lesser dimension of the column.

## MASONRY STRENGTH

The strength and cost of concrete masonry construction increase as stronger concrete units, steel reinforcing, and mortar mixes are used in its construction. When reading the top chart on the facing page, begin by assuming low-strength masonry and read from the lower set of bars. If the wall sizes yielded by this result are impractically large, then consider using higher-strength masonry, reading from the upper set of bars, or interpolate between the two sets.

## CAVITY WALLS

For cavity walls, use only the nominal width of the structural wythe when reading the charts on the facing page.

## MINIMUM WIDTHS OF WALL

For most construction, 8 in. (200 mm) is the minimum practical width for reinforced concrete masonry walls. Though walls 6 in. (150 mm) wide are feasible, they are difficult to construct and only suitable for supporting light loads.

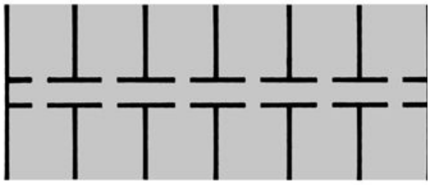
The minimum width for unreinforced masonry walls is 8 in. (200 mm) for the support of light loads; or 12 in. (300 mm) if used for heavier loads. The use of unreinforced masonry construction in modern buildings is rare due to this system's lack of resistance to seismic forces. For more information on the design of loadbearing masonry structures, see Designing with Masonry Bearing Walls on page 82.

## MAXIMUM UNBRACED LENGTH OF WALL

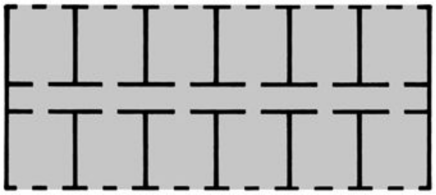
Use the bottom chart on the facing page to determine the maximum permissible unbraced length of wall in plan in addition to its maximum permissible height. Masonry walls should be braced by crosswalls spaced at distances not exceeding those indicated on the chart. If the proposed crosswall spacing in your design is too great, either thicken the wall or add pilasters at intermediate spacing (see pages 86–87 for sizing of pilasters).

## FIRE-RESISTANCE RATINGS FOR CONCRETE MASONRY WALLS

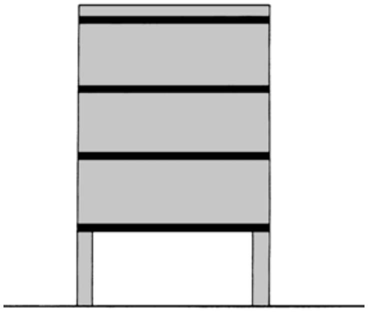
Concrete masonry construction may be used in both Combustible and Noncombustible Construction. The fire resistance of concrete masonry construction varies with the type of masonry unit. For preliminary design, assume that a 1-hour fire-resistance rating can be achieved with a 6-in. (150-mm)-thick wall, a 2-hour rating with an 8-in. (200-mm) wall, and a 3- to 4-hour rating with a 10-in. (250-mm) wall.



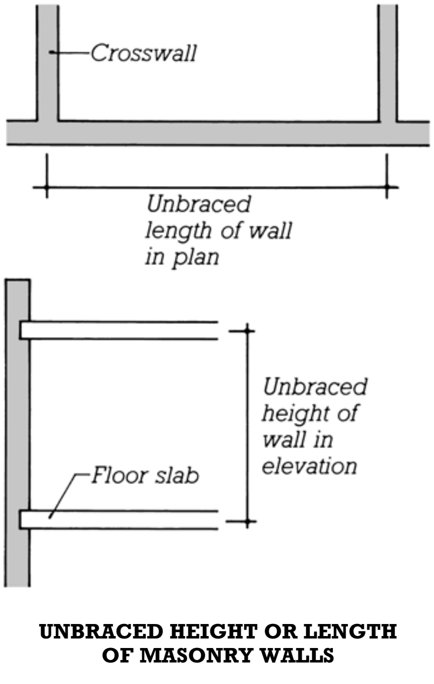
**LOW-RISE BEARING WALL CONFIGURATION** ***(shown in plan)***



**HIGH-RISE BEARING WALL CONFIGURATION** ***(shown in plan)***

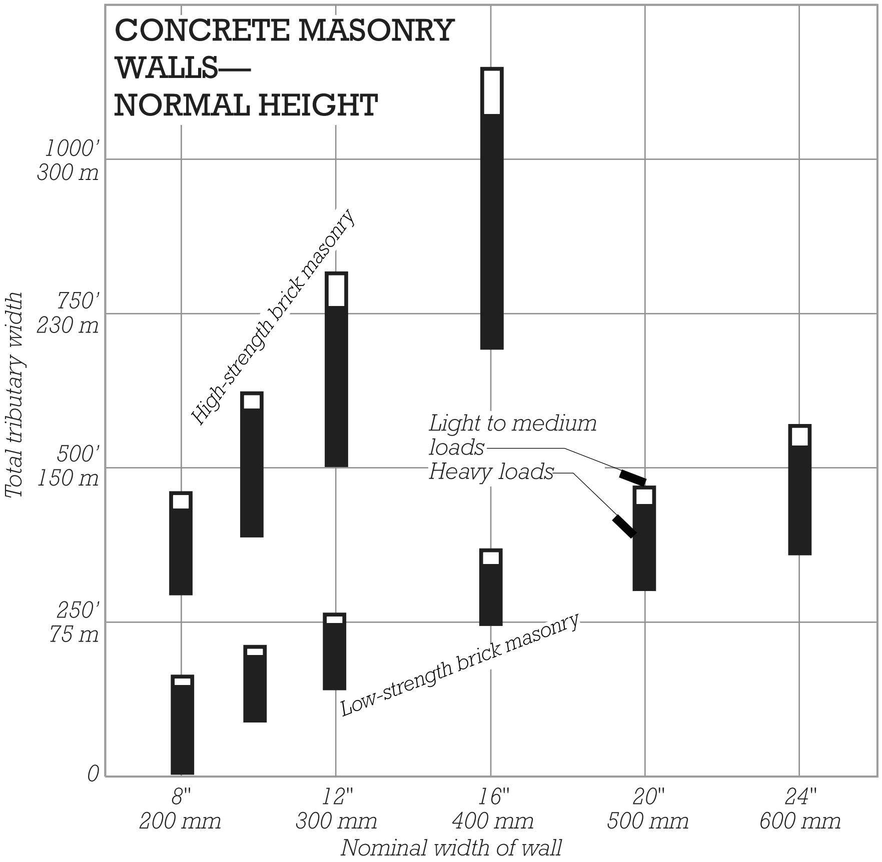


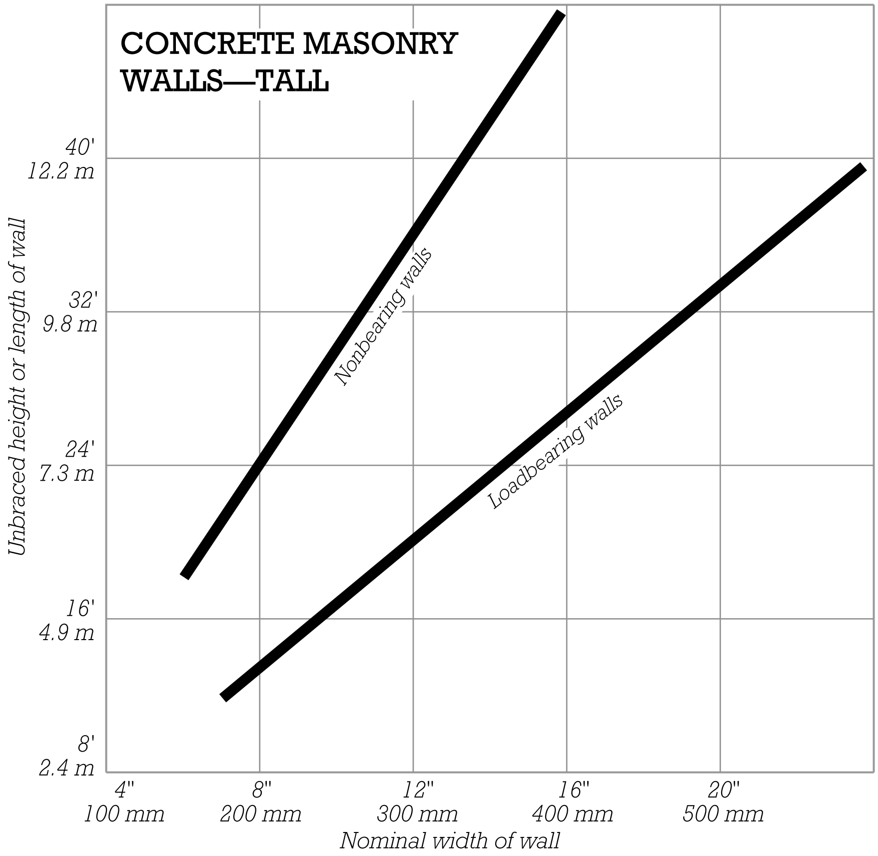
***Bearing walls may act as deep beams to span across openings below, as shown in this schematic cross section.***



**UNBRACED HEIGHT OR LENGTH OF MASONRY WALLS**

# CONCRETE MASONRY WALLS



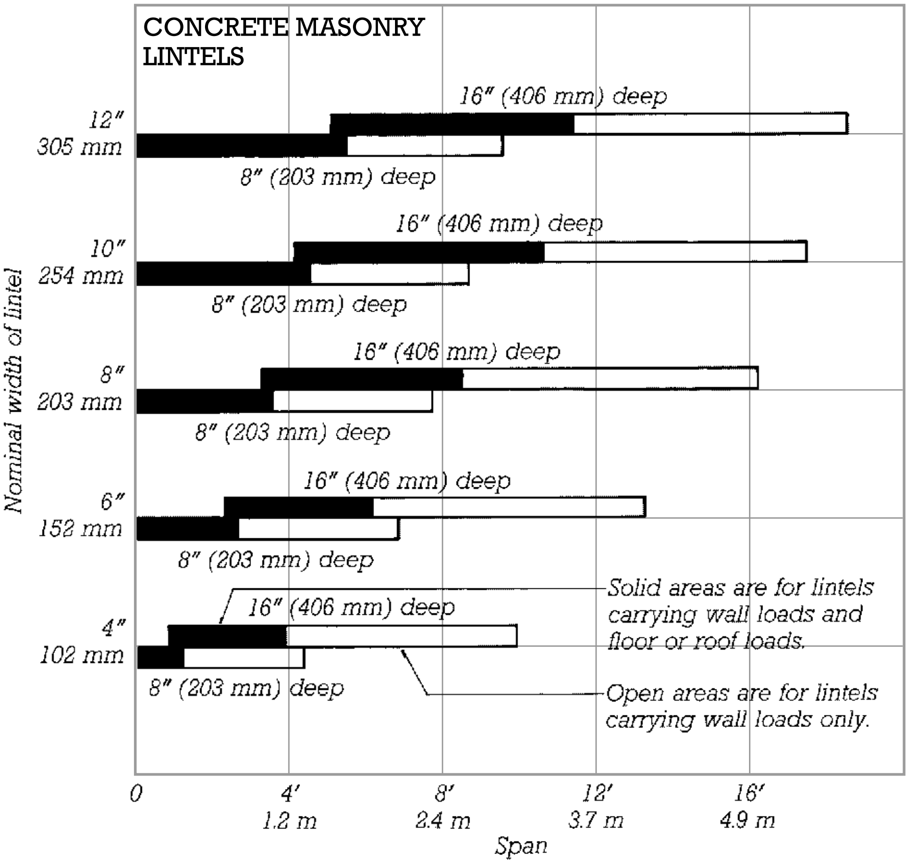


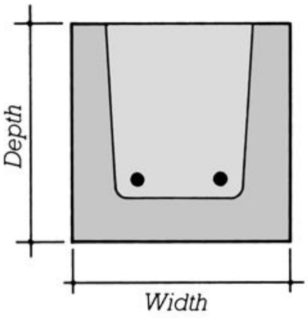
The top chart is for reinforced concrete masonry walls up to 12 ft (3.7 m) tall between floors. For high-compressive-strength masonry, read from the upper set of bars. For low-strength masonry, read from the lower set. For light loads, read in the upper open areas of each bar; for medium to heavy loads, read in the lower solid areas. *Total tributary width* is one-half the span of one floor supported by the wall multiplied by the number of floors and roof above.

■ For unreinforced masonry walls, increase the indicated width of the wall thickness by 25%.

■ Actual width of the wall is 3⁄8 in. (10 mm) less than nominal size.

For walls greater than 12 ft (3.7 m) in height or unbraced length, read from both charts on this page, using the larger size indicated by either chart. Read along the solid line for the appropriate wall type. *Unbraced height of wall* is the vertical distance between floors. *Unbraced length of wall* is the horizontal distance between crosswalls or pilasters. See the facing page for more information on unbraced wall length.





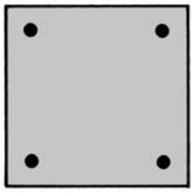
The chart at the left is for steel-reinforced concrete masonry lintels. Open areas are for lintels carrying wall loads only. Solid areas are for lintels carrying wall loads and floor or roof loads. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- ■ Actual sizes are equal to nominal size less ⅜ in. (10 mm).

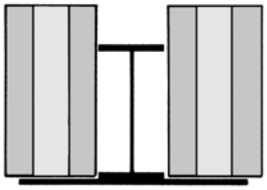
## PRECAST CONCRETE AND STRUCTURAL STEEL LINTELS

Precast concrete lintels that are 8 in. (200 mm) deep can span up to approximately 8 ft (2.4 m). Lintels 16 in. (400 mm) deep can span up to approximately 16 ft (4.9 m).

Lintels made of combinations of steel angles can span up to approximately 8 ft (2.4 m). Greater spans are possible with heavier structural steel shapes, such as channels or wide-flange sections combined with plates.



**PRECAST CONCRETE LINTELS**



**STRUCTURAL STEEL LINTELS**

## FIRE-RESISTANCE RATINGS FOR CONCRETE MASONRY LINTELS

Concrete masonry lintels may be used in both Combustible and Noncombustible Construction. The fire resistance of concrete masonry construction varies with the composition and design of the masonry units themselves. For preliminary design, concrete masonry lintels not less than 8 in. (200 mm) in nominal dimension may be assumed to have a fire-resistance rating of 1 to 2 hours.

# STEEL STRUCTURAL SYSTEMS

Steel elements are of two basic types: Relatively heavy *structural steel* members are formed into their final shapes by hot-rolling. This method produces such common elements as wide-flange sections, angles, channels, bars, and plates. *Lightweight steel framing* members are cold-formed from thin sheets or rods. Such elements include roof and floor decking and a variety of light framing members such as channels, studs, and joists.

## STRUCTURAL STEEL FRAMING

Conventional hot-rolled structural steel is a versatile material that has applications ranging from single-story structures to the world's tallest buildings. The extent of prefabrication normally used with structural steel results in a system that is precise and rapidly erected.

Structural steel elements are normally configured as a post and beam frame, with other components added to make a complete building. The slab system most commonly used with structural steel framing is a sitecast concrete slab poured over corrugated steel decking. Other sitecast or precast concrete systems are also used. Steel frames can support all variety of cladding systems, with curtain walls of steel, aluminum, glass, masonry, and stone being the most common.

Due to steel's rapid loss of strength at elevated temperatures, it must often be concealed behind fire-resistive materials or assemblies. See pages 380–382 for more information on the requirements for fire protection of structural steel.

## LIGHTWEIGHT STEEL FRAMING

Lightweight steel framing (also called *light gauge steel framing*) finds applications in low-rise structures where the light weight and ease of assembly of these elements are advantages. Many of the details of this system and the sizes of the structural elements are similar to those used in Wood Light Frame Construction, a system lightweight steel framing often competes with. However, the noncombustibility of steel allows this system to be used in building types where wood construction is not permitted. The small size of the individual structural elements and the reliance on on-site fabrication also make this system a good choice where buildings of irregular form are desired. See pages 380–382 for more information on the building types permitted using lightweight steel framing.

## SIZE, WEIGHT, AND SPACING OF LIGHTWEIGHT STEEL STUDS

The charts on the facing page list the most commonly available sizes of lightweight steel studs. Other sizes may be available from some manufacturers. Studs typically vary in width from 1⅜ to 2½ in. (35 to 64 mm). For preliminary purposes, a width of 2 in. (50 mm) may be assumed.

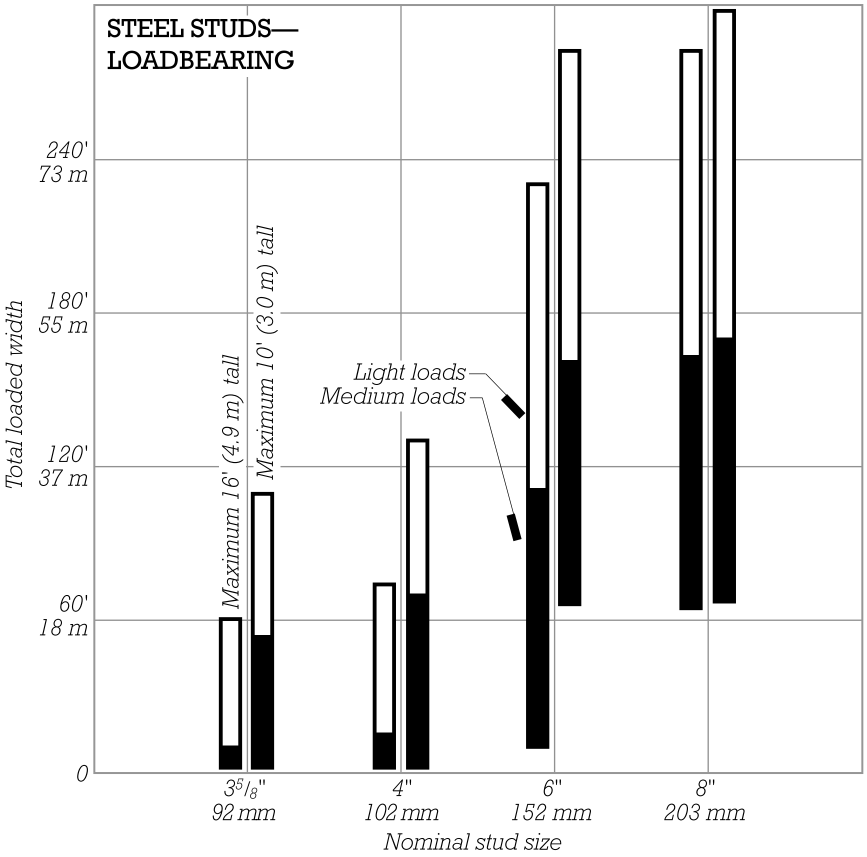
The load-carrying capacity of lightweight steel studs varies with the strength and thickness of the steel sheet from which the studs are made. When reading the charts on the facing page, the highest values indicated in each stud size represent studs manufactured from thicker, higher-strength metal. Lower values represent studs manufactured from thinner, lower-strength material.

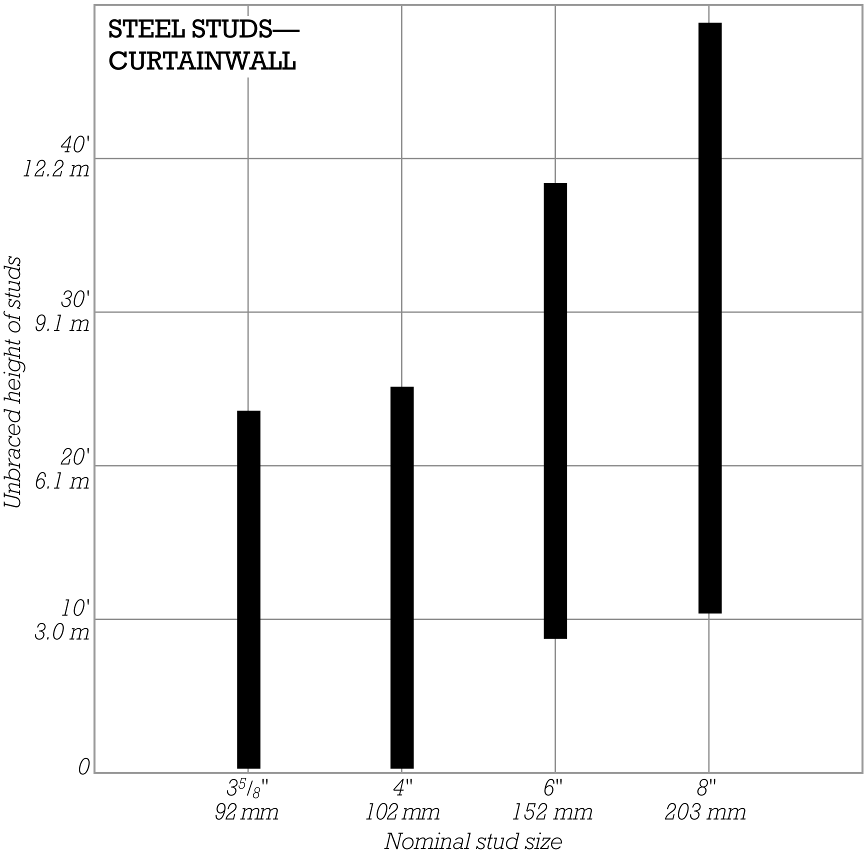
The capacity of steel stud systems also depends on the spacing of the studs. Studs should always be spaced on a 4-ft (1200-mm) module to coordinate with standard wall panel widths. The most common spacings are 12, 16, and 24 in. (300, 400, and 600 mm) on center. When reading the charts on the facing page, the highest values shown for each stud size represent framing systems with studs spaced at 12 in. (300 mm). Lower values represent systems with studs spaced at 16 or 24 in. (400 or 600 mm).

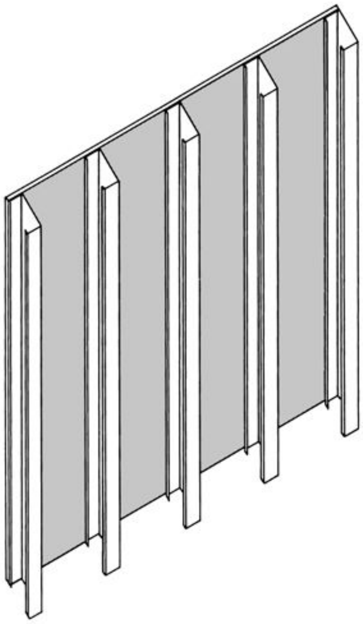
## FIRE-RESISTANCE RATINGS FOR STEEL STUD FRAMING

Lightweight steel stud construction may be used in both Combustible and Noncombustible Construction. To achieve a 1-hour fire-resistance rating, framing may be covered with rated gypsum wallboard or plaster materials in thicknesses ranging from ½ to 1 in. (12 to 25 mm). Fire-resistance ratings of up to 4 hours can be achieved with finishes ranging in thickness from 2 to 3 in. (50 to 75 mm). Even where no fire-resistance rating is required, steel stud framing typically must be covered with some form of wallboard or panel material to stabilize its relatively slender members against buckling.

# LIGHTWEIGHT STEEL WALL STUDS







The top chart is for loadbearing lightweight steel stud walls. For walls up to 10 ft (3.0 m) high, read from the taller right-hand bars. For walls up to 16 ft (4.9 m) high, read from the left-hand bars. For light loads, read in the open areas of each bar. For medium loads, read in the solid areas. *Total loaded width* is the tributary width of one floor (one-half of its span) multiplied by the number of floors and roof above the wall.

■ Actual stud depth is equal to the nominal size.

The lower chart is for curtain wall studs—studs resisting wind but not gravity loads. For light wind loads and for cladding systems such as glass or metal that are relatively tolerant of deflection, read toward the top in the indicated areas. For heavy wind loads and for claddings of stone, clay masonry, or other materials requiring stiffer support, read toward the bottom. *Unbraced height of studs* is the vertical distance between floors or other supports.

■ Stud height may be increased with the addition of intermediate bracing perpendicular to the wall plane.

## SIZE, WEIGHT, AND SPACING OF LIGHTWEIGHT FLOOR JOISTS

The chart on the facing page lists the most commonly available sizes of lightweight steel floor joists. Other sizes may be available from some manufacturers. Joists typically vary in width from 1⅝ to 2½ in. (35 to 64 mm). For preliminary purposes, a width of 2 in. (50 mm) may be assumed.

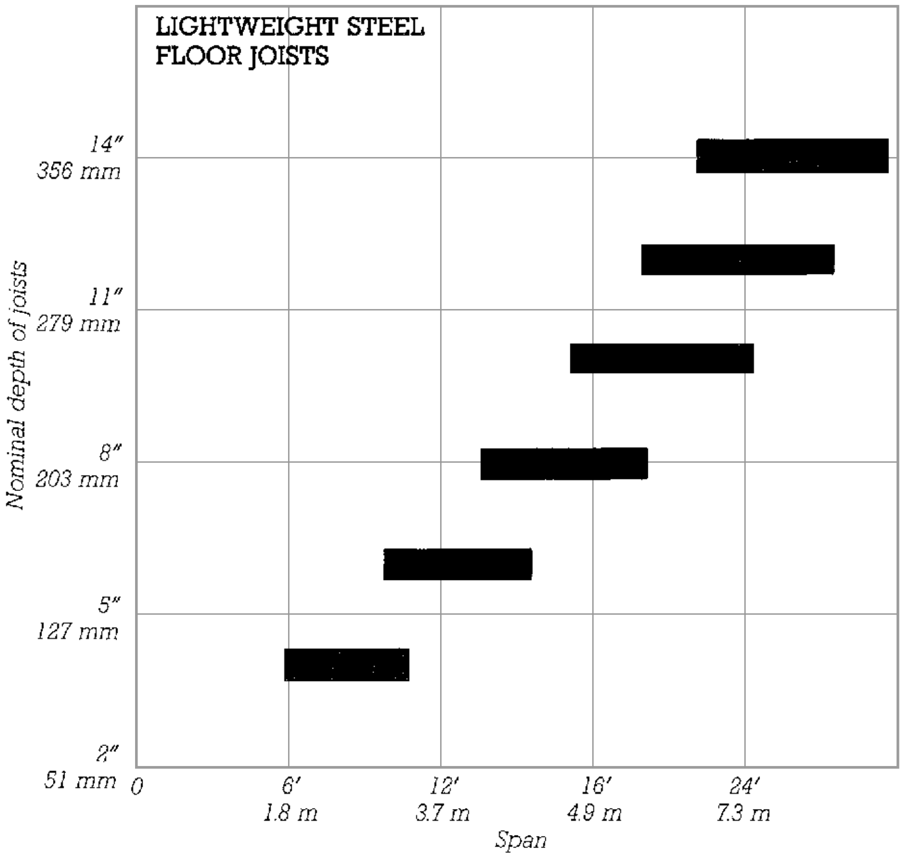
The load-carrying capacity of lightweight steel joists varies with the strength and thickness of the steel sheet from which the joists are made. When reading the chart on the facing page, the longest spans indicated in each joist size represent joists manufactured from thicker, higher-strength sheet metal. Shorter spans represent joists manufactured from thinner, lower-strength material.

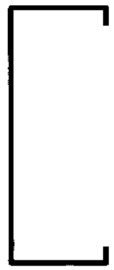
The capacity of steel joist framing also depends on the spacing of the joists. Joists should always be spaced on a 4-ft (1200-mm) module to coordinate with standard floor panel widths. The most common spacings are 16 and 24 in. (400 and 600 mm) on center. When reading the chart on the facing page, the longest spans shown for each joist size represent framing with joists more closely spaced, and shorter spans represent systems with joists at greater spacings.

## FIRE-RESISTANCE RATINGS FOR LIGHTWEIGHT STEEL

Lightweight steel floor joists may be used in both Combustible and Noncombustible Construction. Fire-resistance ratings of 1 to 2 hours may be achieved with ceilings of gypsum board or plaster in thicknesses ranging from 1 to 2 in. (25 to 50 mm)

# LIGHTWEIGHT STEEL FLOOR JOISTS





This chart is for lightweight steel floor joists. For light loads, close joist spacings, or joists made from stronger, thicker steel sheet metal, read toward the right in the indicated areas. For heavy loads, wide spacings, or studs made of less strong, thinner sheet metal, read toward the left.

■ Actual size is equal to nominal size less from 0 to ¾ in. (19 mm), depending on the manufacturer.

## COLUMN LAYOUT

Columns at the perimeter of a building should be oriented with their flanges facing outward wherever possible to facilitate the attachment of cladding to the building's structural frame. Elsewhere, columns should be oriented with their webs parallel to the axis on which the building is most vulnerable to lateral forces so that the columns may make the greatest contribution to resisting these forces. For example, in buildings with rectangular footprints, the weaker axis is most frequently parallel to the shorter sides of the structure, and orienting column webs that are parallel to this shorter axis would be preferred.

## FINISH DIMENSIONS OF STEEL COLUMNS

In most cases, structural steel columns are not exposed in the completed construction, and their overall finish dimensions must be increased from those shown in the charts on the facing page to account for the application of fireproofing and finishes. The added thickness depends on the materials involved, the degree of fire resistance required, and the weight of the steel section itself (heavier sections require less added fire protection than lighter ones). For common conditions, an allowance of 1 to 4 in. (25 to 100 mm) per side of column should be sufficient for preliminary sizing. When applying these allowances to the actual column sizes, remember to double them to account for materials applied to opposite sides of the column, that is, 2 to 8 in. (50 to 200 mm) total.

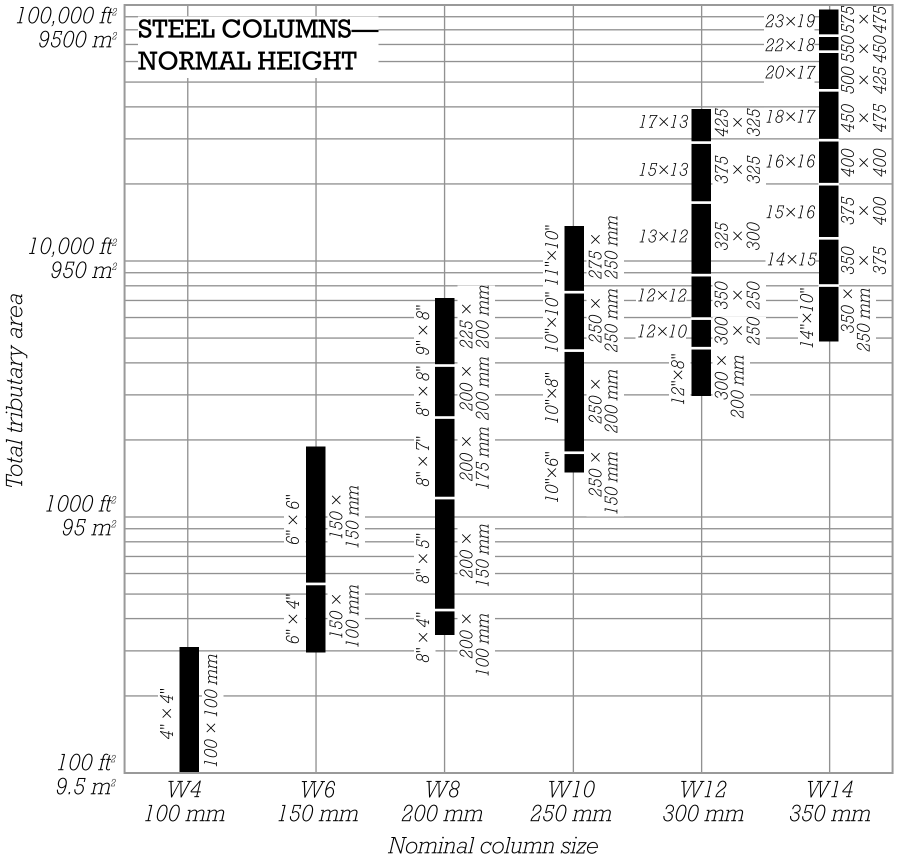
As a more costly alternative, in cases where fire protection is required but there is a desire for steel to remain exposed, thin paint-like intumescent coatings may be applied to the steel. Under normal conditions, these coatings add only negligibly to the size of the column. Under fire conditions, they expand to form an insulating layer that protects the steel from the heat of the fire.

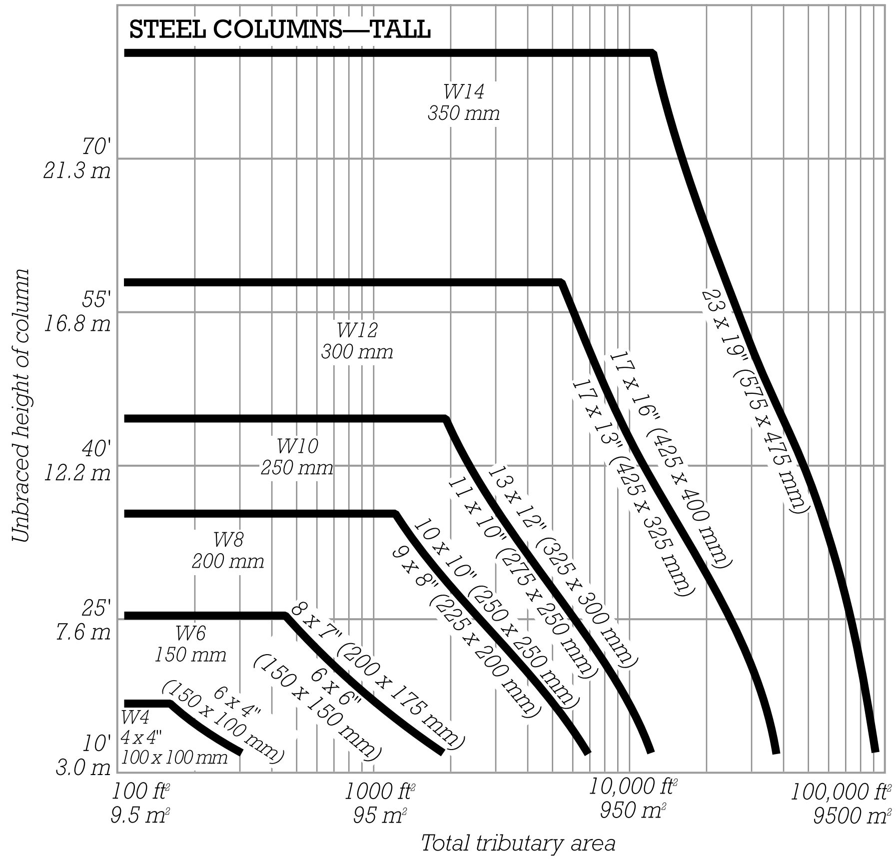
Depending on how individual sections of the column are connected, an additional allowance of 1 to 2 in. (25 to 50 mm) per side may be required, added to the deeper dimension of the column, to account for splice plates and fasteners where column joints occur. Where required, these connections typically are located several feet above the floor level.

## FIRE-RESISTANCE RATINGS FOR STRUCTURAL STEEL COLUMNS

Exposed structural steel columns may be used in both Unprotected Noncombustible and Unprotected Combustible Construction. For Protected Construction types, fire-resistance ratings of up to 4 hours are easily achieved with any number of conventional fireproofing materials in thicknesses of as little as 1 to 4 in. (25 to 100 mm). As an alternative, intumescent coatings, as described above, can provide up to 3 hours of fire resistance.

# STRUCTURAL STEEL COLUMNS





The top chart is for steel wide-flange section columns up to 12 ft (3.7 m) tall between floors. *Total tributary area* is the summed area of the roof and all floors supported by the column.

- For medium loads, read directly from the chart. For light loads, reduce the total tributary area supported by the column by 10% before reading the chart; for heavy loads, increase the area supported by 15%.
- Actual column sizes are shown to the sides of the bars. Not all available sizes are shown. Consult a steel handbook for additional options.
- For columns located at the perimeter of a building or forming part of a rigid frame system, select one nominal size larger than the least nominal size indicated by this chart.
- W14 sections are the largest standard rolled sizes commonly available for use as columns. Larger built-up sections capable of carrying greater loads may be shop-fabricated.

For columns taller than 12 ft (3.7 m), read from both charts on this page, using the larger column size indicated by either one. *Unbraced height of column* is the vertical distance between floors or other supports that brace the column laterally against buckling.

- Actual column sizes are shown alongside the nominal shape curves. Intermediate sizes between those shown may be interpolated.
- Minimum column size will be larger for heavily loaded columns or columns that are part of rigid frame systems.

## STRUCTURAL HOLLOW STEEL SECTIONS

Standard shapes for structural hollow steel sections (commonly abbreviated as HSS on structural drawings and in technical literature) include square tubes, rectangular tubes, and round pipes. Compared to wide-flange sections of the same weight, tubes and pipes are more resistant to buckling forces, making them good choices for columns and compressive struts in all types of steel systems. They are employed as columns in long-span steel structures for their greater efficiency, and because they are available in lighter weights than other standard shapes, they are frequently used in one- or two-story steel structures as well. HSS members are popular choices for use in the fabrication of steel trusses and space frames, and their high torsional resistance makes them excellent choices for single post supports such as for signs or platforms.

The simple profiles and clean appearance of hollow steel sections and pipes also make them popular for use where the steel may remain visible in the finished structure, or for structures exposed to the weather where the absence of moisture- and dirt-trapping profiles and ease of maintenance are desirable characteristics. Tubes and pipes are generally available in whole-inch (25-mm) sizes up to 6 or 8 in. (152 or 203 mm) and in even-inch (51-mm) increments up to 12 to 16 in. (305 to 406 mm).

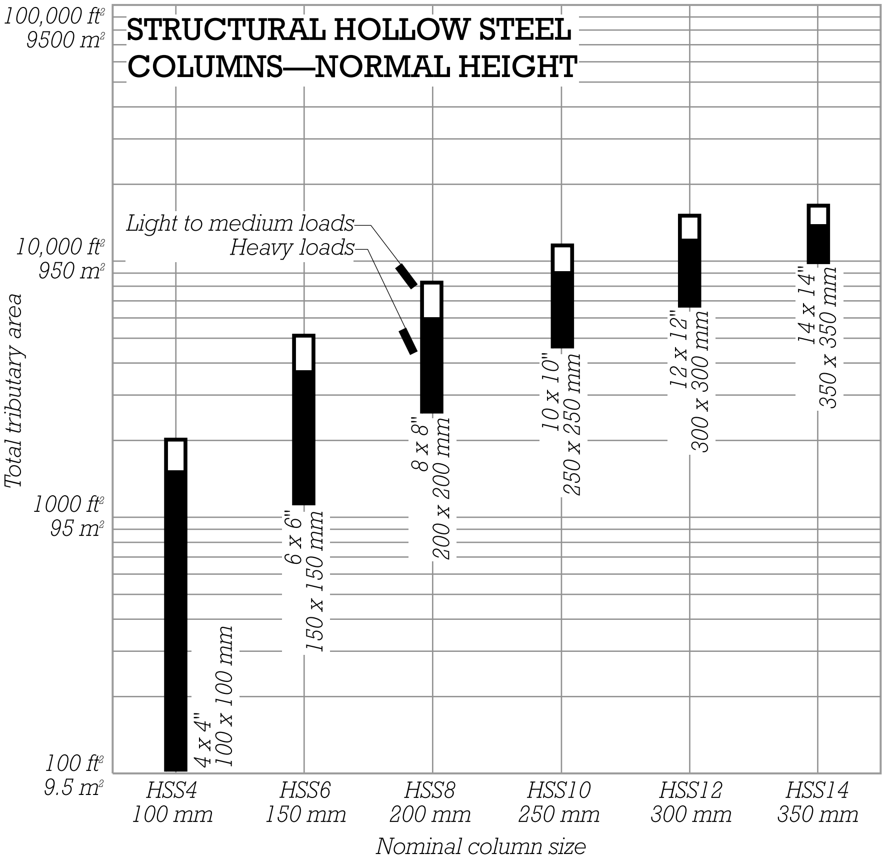
## FINISH DIMENSIONS OF HOLLOW STEEL SECTION COLUMNS

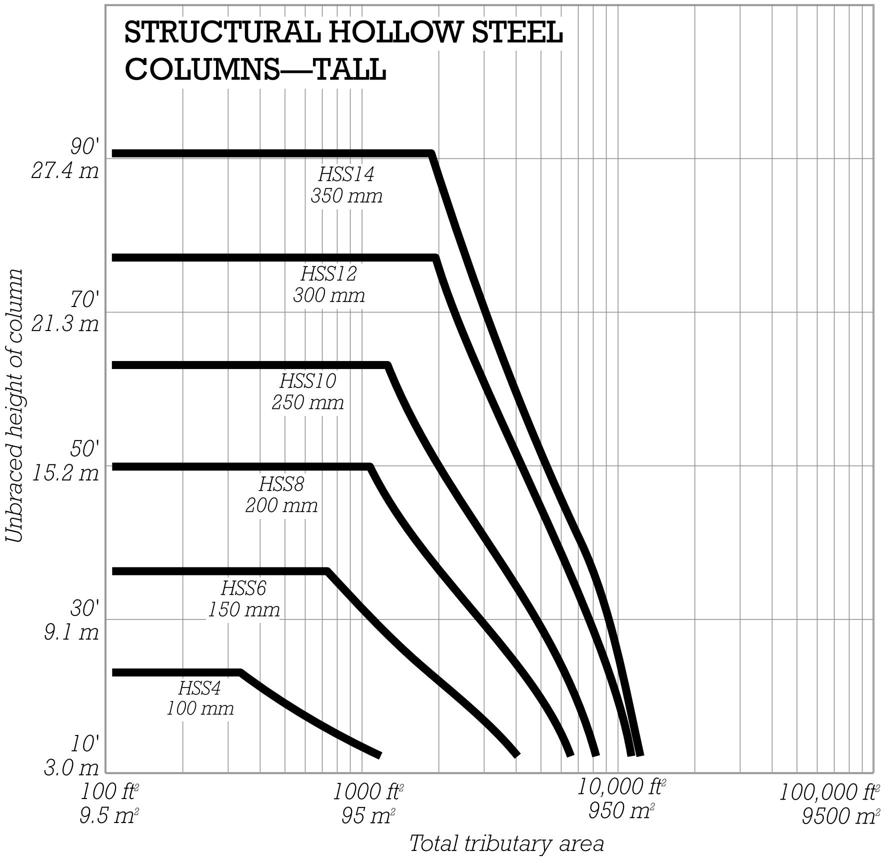
Where finishes are applied to hollow steel section columns, the added thickness depends on the materials involved, the degree of fire resistance required, and the weight of the steel section itself (heavier sections require less added fire protection than lighter ones). For preliminary sizing, an allowance of 1 to 4 in. (25 to 100 mm) per side of column should be sufficient (a total of 2 to 8 in. or 50 to 200 mm, accounting for both sides of the column). In cases where fire protection is required but there is a desire for steel to remain exposed, more costly paint-like intumescent coatings may be applied to the steel. Under fire conditions, these normally thin coatings expand to form an insulating layer that protects the steel from the heat of the fire.

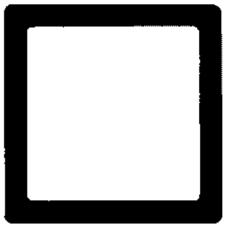
## FIRE-RESISTANCE RATINGS FOR HOLLOW STEEL SECTION COLUMNS

Exposed hollow steel section columns may be used in both Unprotected Noncombustible and Unprotected Combustible Construction. For Protected Construction Types, fire-resistance ratings of up to 3 hours for very light sections and 4 hours for heavier ones are achievable with any number of conventional fireproofing materials applied in thicknesses of 2 to 4 in. (100 to 200 mm) per side. Fire-resistance ratings of up to 3 hours can also be achieved with intumescent coatings, as described above, or with specially designed hollow section columns filled with concrete.

# STRUCTURAL HOLLOW STEEL COLUMNS







The top chart is for hollow steel section columns up to 12 ft (3.7 m) tall between floors. Read in the top open areas for light and medium loads. Read in the lower solid areas for heavy loads. *Total tributary area* is the summed area of the roof and all floors supported by the column.

■ Actual column size is equal to nominal size.

■ For columns located at the perimeter of a building, or ones that are part of a rigid frame system, select one nominal size larger than size indicated by this chart.

For columns taller than 12 ft (3.7 m), read from both charts on this page, using the larger column size indicated by either one. *Unbraced height of column* is the vertical distance between floors or other supports that brace the column laterally against buckling.

■ Minimum column size will be larger for heavily loaded columns or columns that are part of rigid frame systems.

## STEEL FLOOR DECKING

Corrugated steel floor decking with a sitecast concrete topping is the slab system most commonly used over structural steel framing. Typical span ranges for steel floor decking used with structural steel framing are 6 to 15 ft (1.8 to 4.6 m). Longer spans or shallower depths than those indicated on the chart on the facing page may be possible, although increased construction costs may result from the need for additional temporary shoring of the decking during erection.

## CELLULAR FLOOR DECKING

The use of cellular decking to provide concealed spaces within the floor slab for the running of electrical and communications wiring may influence the framing plan for the building. Layout requirements for such wiring systems may determine the direction in which the decking cells will run in various areas of the building plan. The orientation of the beams or joists carrying the decking will, in turn, run perpendicular to the cells in the decking. See page 207 for additional information on the planning of such systems.

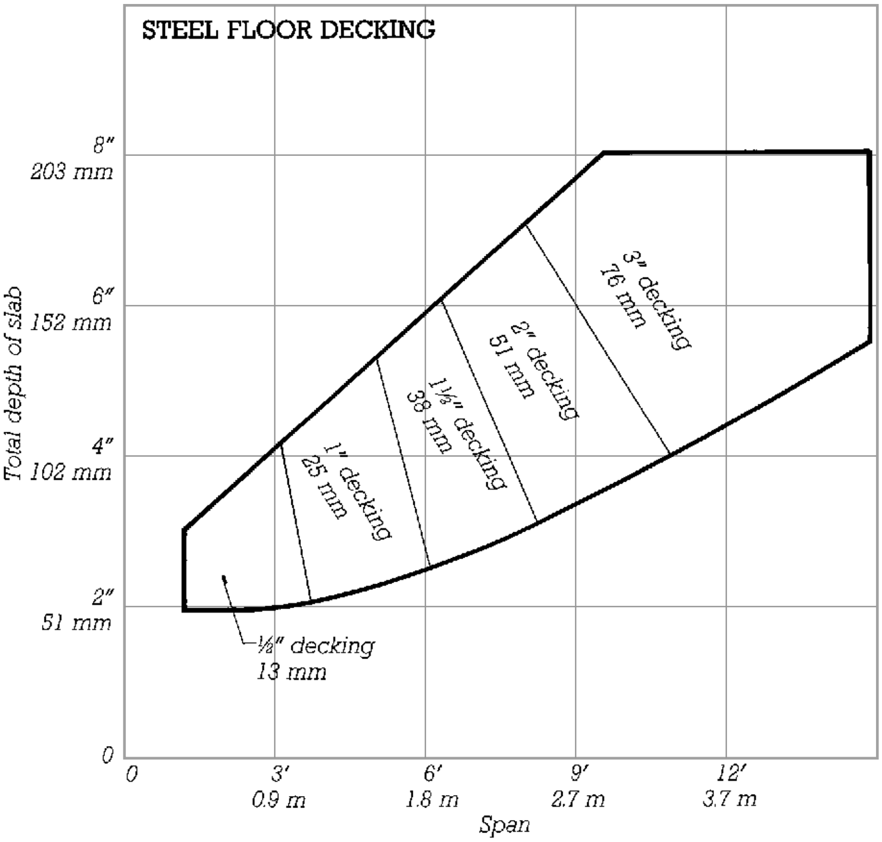
## STEEL ROOF DECKING

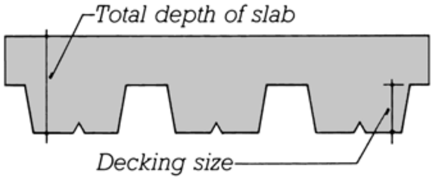
Steel roof decking may have a sitecast concrete or gypsum topping or may be covered directly with a variety of board or roofing products. A common and economical configuration for roof decking is 1½-in. (38-mm) metal decking spanning up to 8 ft (2.4 m). Many proprietary metal roof decking systems, with a wide variety of performance characteristics, are available. Consult manufacturers for more information.

## FIRE-RESISTANCE RATINGS FOR STEEL DECKING

Steel roof and floor decking may be used in both Combustible and Noncombustible Construction. The fire resistance of roof or floor decking with a concrete topping varies with the configuration of the decking and the thickness of the topping. Though resistance ratings of as high as 3 hours may be possible, for preliminary design, assume that decking must be protected with applied fireproofing or an appropriately fire-resistive ceiling to achieve ratings of more than 1 hour.

# STEEL FLOOR AND ROOF DECKING



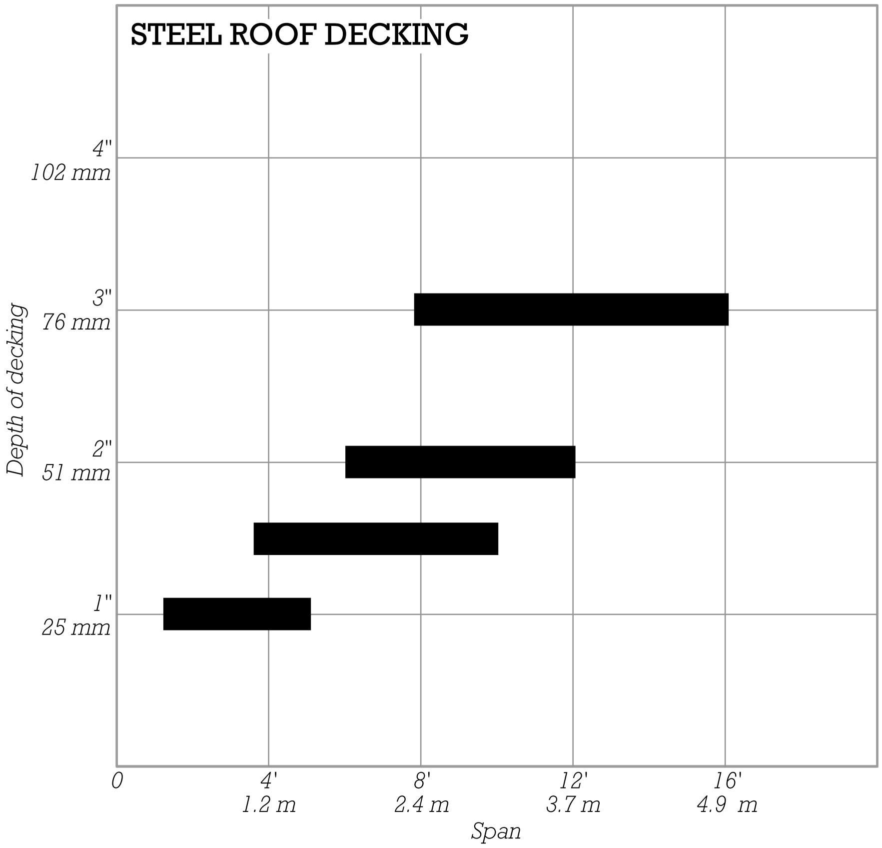


The top chart is for corrugated or cellular steel floor decking with concrete slab topping. For light loads, read toward the bottom in the indicated areas. For heavy loads, read toward the top.

■ *Total depth of slab* is the combined depth of the decking and the concrete topping. Approximate sizes for the steel decking alone are shown within the chart.

■ For cellular decking, read toward the bottom in the indicated areas.

■ Deeper deck sections with span capabilities exceeding 30 ft (9 m) are available from some manufacturers.



The bottom chart is for corrugated steel roof decking. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

■ Deeper section decking with spans exceeding 30 ft (9 m) is available from some manufacturers.

# STRUCTURAL STEEL BEAMS AND GIRDERS

Structural steel is a versatile building material. While it can be used in a great variety of ways, consider the following guidelines for what is most economical in common practice.

## FLOOR AND ROOF FRAMING

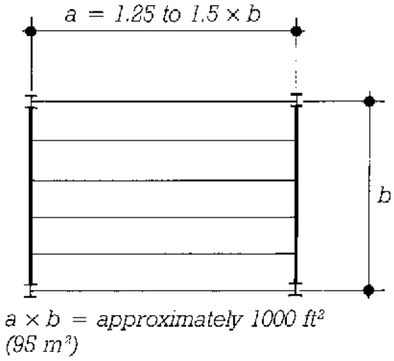
The most economical span range for conventional steel floor and roof framing is 25 to 40 ft (8 to 12 m). Individual column bays should be approximately 1000 sq ft (95 $m^2$) in area and rectangular in shape, with the long side 1.25 to 1.5 times as long as the shorter side. Above spans of approximately 40 ft (12 m), consider open-web steel joists for their lighter weight and greater economy (see page 104).

The spacing between individual beams depends on the applied loads and the decking system. Spacings from 6 to 15 ft (1.8 to 4.6 m) are common with corrugated steel and concrete slab decking. Spacings up to approximately 8 ft (2.4 m) are typical for roof decking systems.

## BEAM AND GIRDER CONFIGURATION

The orientation of beams and girders in a floor or roof framing system may depend on a variety of factors. In relation to the building at large, it may be advantageous to run girders parallel to the building's shorter axis, the direction most susceptible to lateral forces. In this way, these stronger members can contribute additional lateral resistance to the building through rigid frame action.

Within individual column bays, it is usually more economical to run girders in the shorter direction of a rectangular bay, allowing the lighter beams to span the longer distance. However, when cellular decking is used as part of a wiring system, beam and girder directions may be set so that the wire conduits within the decking run in preferred directions as required by communications or power distribution plans (see page 207).

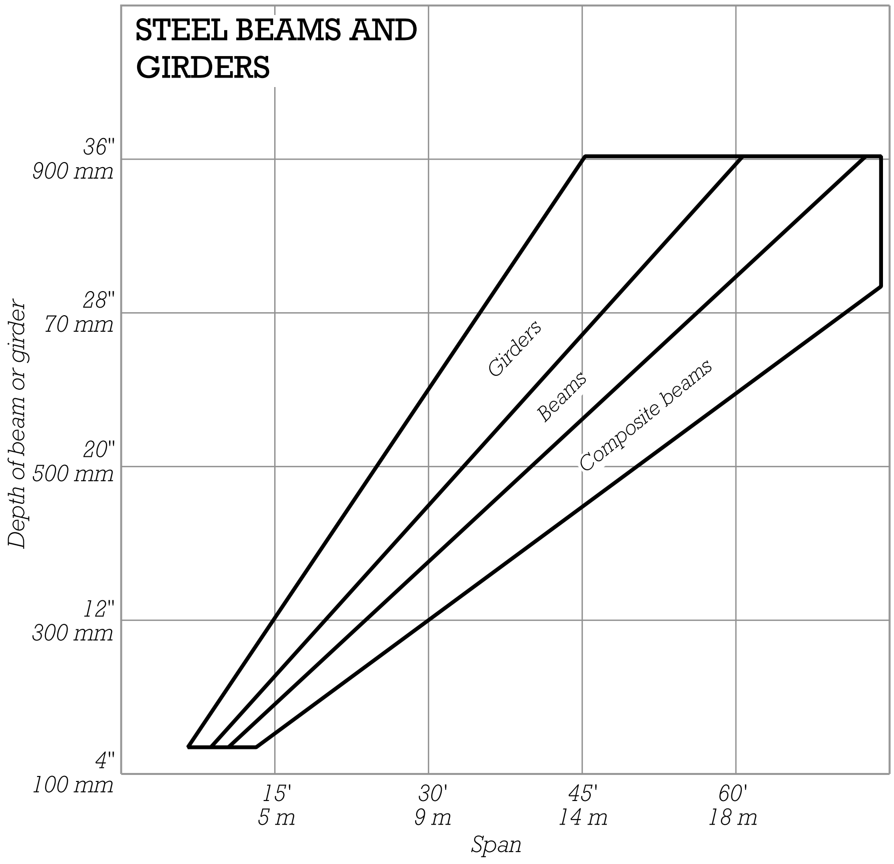


***For economical framing of steel bays, the lighter beams should span 1.25 to 1.5 times the span of the heavier girders. Bay area should equal approximately 1000 $ft^2$ (95 $m^2$).***

## COMPOSITE BEAMS

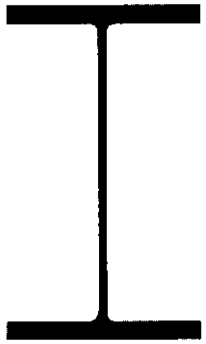
In composite construction, shear studs are added to the top of the floor beams. This causes the concrete deck and steel framing to act as a unified structural element and results in reduced beam depths. Composite construction can be more economical, particularly at longer spans. However, a thicker concrete deck may be required. In some cases, a so-called *partial composite design,* in which fewer studs are used and less than full composite action is achieved, proves to be the most economical solution.

# STRUCTURAL STEEL BEAMS AND GIRDERS



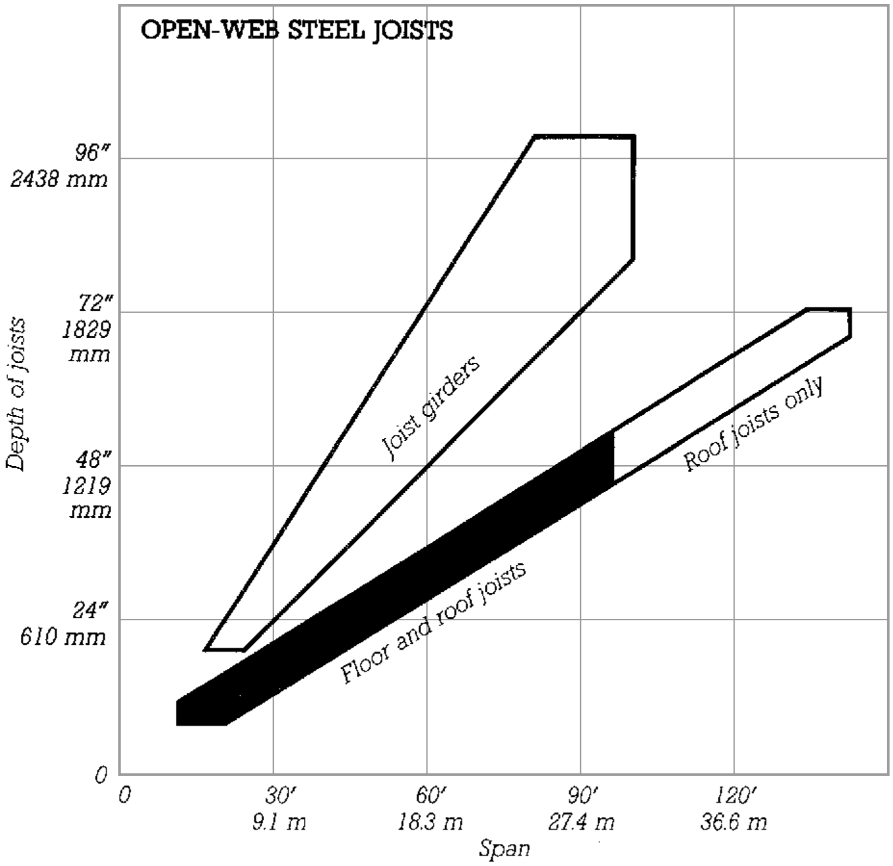
## FIRE-RESISTANCE RATINGS FOR STEEL BEAMS AND GIRDERS

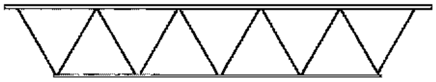
Steel beams and girders may be used in both Combustible and Noncombustible Construction. Fire-resistance ratings of as high as 4 hours are achievable with applied fireproofing or an appropriately fire-resistive ceiling. Some building codes also allow reduced fire protection or exposed steel for roof structures that are 15 to 25 ft (4.6 to 7.6 m) or more above the floor.



This chart is for steel wide-flange beams, composite beams, and girders. For average and light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- Beams or girders acting as part of a rigid frame for lateral stability may be deeper than indicated by this chart.
- Standard depths of shapes come in 2-in. (50-mm) increments up to 18 in. (450 mm) deep, and in 3-in. (75-mm) increments for larger sizes.
- Widths of beams and girders range from approximately one-third to one-half the depth of the member. Heavy sections used for heavy loads or to conserve depth may be wider.
- Depths of up to 36 in. (914 mm) are available as standard rolled sections. Deeper beams capable of longer spans may be shop-fabricated.





This chart is for open-web steel joists and joist girders for floors and roofs. For light loads or close joist spacings, read toward the right in the indicated areas. For heavy loads or large joist spacings, read toward the left.

- ■ Joist spacings range from 2 to 10 ft (0.6 to 3.0 m) or more, depending on the floor loads and the decking system applied over the joists.
- ■ Joists generally come in depths of 8 to 32 in. in 2-in. increments (203 to 813 mm in 51-mm increments) and from 32 to 72 in. in 4-in. increments (from 813 to 1829 mm in 102-mm increments). Availability of sizes varies with the manufacturer.
- ■ Joist girders come in depths of 20 to 96 in. in 4-in. increments (508 to 2438 mm in 102-mm increments).

## OPEN-WEB JOIST FRAMING

The light weight of open-web steel joists makes them an economical alternative to conventional structural steel members for spans greater than 30 to 40 ft (9 to 12 m). Where significant concentrated loads exist, open-web joists may need to be supplemented with additional structural members.

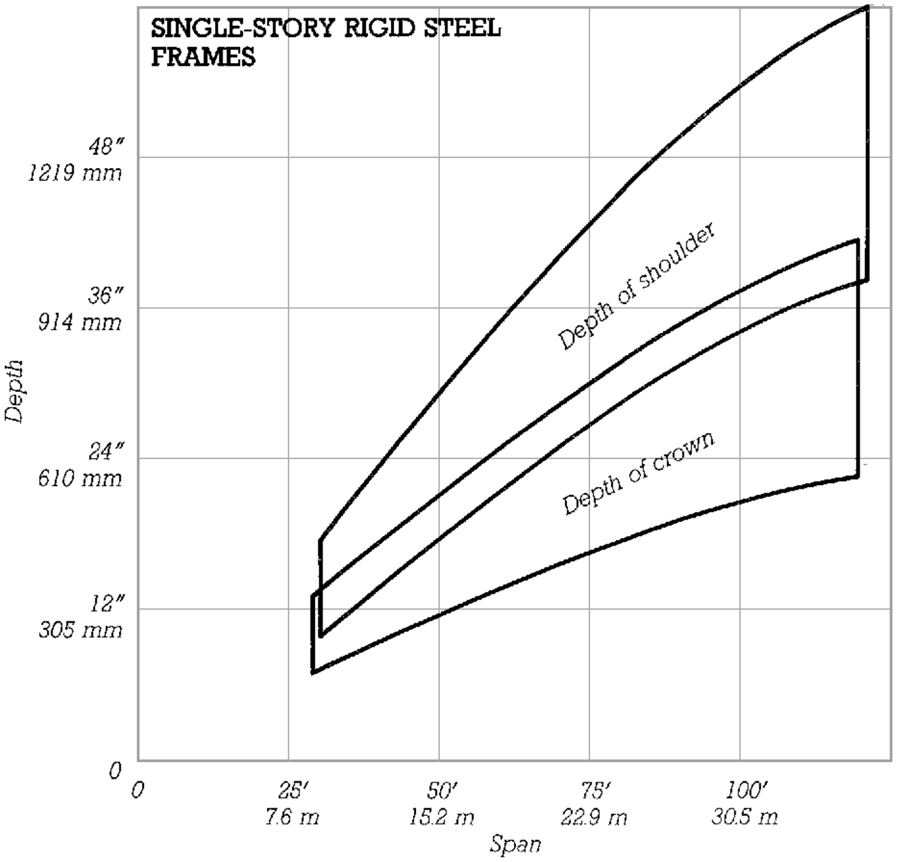
Girders used with open-web joists may be joist girders (a heavier version of an open-web joist) or conventional structural steel members. For greater loads and spans, heavy steel trusses may also be used. For rectangular bays, the joists usually span the longer direction. (See pages 102–103 for structural steel beams and girders and page 106 for heavy steel trusses.)

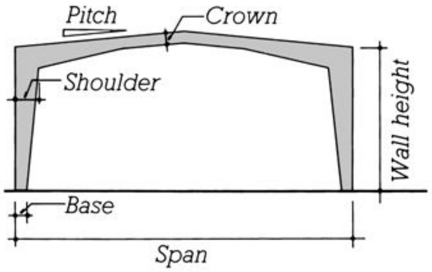
A variety of proprietary composite systems are also available. Such systems are particularly effective at overcoming the excessive flexibility sometimes encountered with long-span joist systems.

## FIRE-RESISTANCE RATINGS FOR OPEN-WEB STEEL JOISTS

Open-web steel joists may be used in both Combustible and Noncombustible Construction. Fire-resistance ratings of as high as 3 hours are achievable with applied fireproofing or an appropriately fire-resistive ceiling. Some building codes also permit reduced fire protection or exposed steel for roof structures that are 15 to 25 ft (4.6 to 7.6 m) or more above the floor.

# SINGLE-STORY RIGID STEEL FRAMES





This chart is for single-story rigid steel frame structures within the dimensional limits indicated below. For heavy loads, read toward the top in the indicated areas. For light loads, read toward the bottom. For other configurations, consult manufacturers.

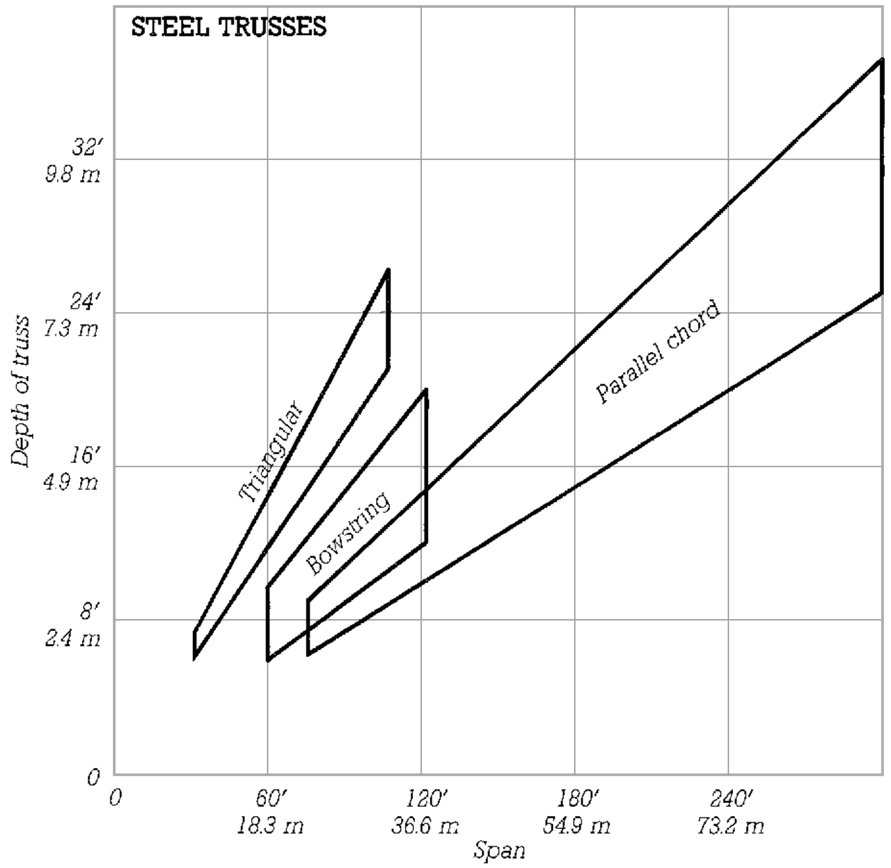
- Roof pitch: ½:12 to 4:12
- Wall height: 8 to 30 ft (2.4 to 9.1 m)
- Depth at base: 7 to 21 in. (180 to 535 mm)

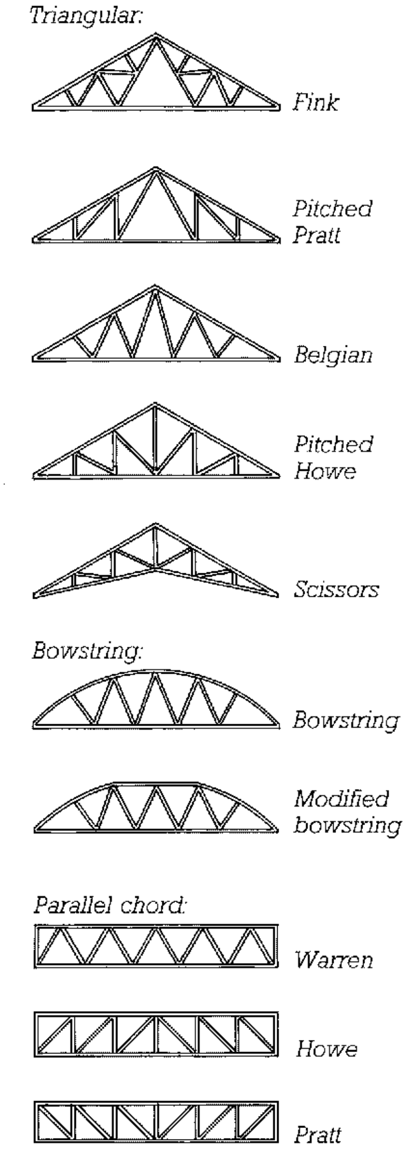
## SINGLE-STORY RIGID STEEL FRAME CONFIGURATIONS AND SPANS

Single-story rigid steel framing systems come in a variety of configurations capable of clear spans exceeding 300 ft (90 m), or even further with the addition of intermediate columns. Roof pitches may range from ½:12 to 12:12. Typical frame spacing is 20 to 25 ft (6.1 to 7.6 m), or as much as 40 ft (12 m) when used with wall and roof systems capable of spanning the greater distance between frames.

## FIRE-RESISTANCE RATINGS FOR SINGLE-STORY RIGID STEEL FRAMES

Single-story rigid steel frames may be used in both Combustible and Noncombustible Construction. Fire-resistance ratings of as high as 4 hours are achievable with applied fireproofing. Some building codes also allow reduced fire protection or exposed steel for roof structures that are 15 to 25 ft (4.6 to 7.6 m) or more above the floor.





## ECONOMICAL SPAN RANGES FOR PARALLEL CHORD TRUSSES

Parallel chord trusses are most economical for spans up to 120 to 140 ft (35 to 45 m) due to the increased difficulty of shipping elements greater than 12 ft (3.7 m) deep. Triangular and bowstring trusses can be shipped at slightly greater depths. Trusses spanning 300 ft (90 m) or more may be shipped in sections and assembled on site.

## FIRE-RESISTANCE RATINGS FOR STEEL TRUSSES

Structural steel trusses may be used in both Combustible and Noncombustible Construction. Fire-resistance ratings of as high as 4 hours are achievable with applied fireproofing or an appropriately fire-resistive ceiling. Some building codes also allow reduced fire protection or exposed steel for roof structures that are 15 to 25 ft (4.6 to 7.6 m) or more above the floor.

The chart on this page is for steel trusses fabricated from structural steel members. Because these trusses are custom designed and fabricated, a great variety of shapes and configurations is possible.

The choice of sitecast concrete framing systems is constrained by the required spans (the spacing between walls or columns) and by the magnitude of the in-service loads. The following systems are listed in order of increasing span and load capacity. Those listed in bold type are generally the most economical within their span range.

- One-Way Solid Slab
- **Two-Way Flat Plate**
- **Two-Way Flat Slab**
- **One-Way Joist**
- Waffle Slab
- One-Way Beam and Slab
- Two-Way Beam and Slab

For lightly loaded, short span conditions, consider systems from near the top of the list. For longer spans or heavier loads, consider systems lower down. Where cost is a primary consideration, preference should be given to those systems listed in bold type.

## POSTTENSIONING

The span ranges of sitecast concrete systems can be increased by the use of posttensioned reinforcing (high-tensile-strength steel cable reinforcing within the concrete that is stretched tight after the concrete has cured). Charts for the sizing of posttensioned systems are included in this section. Posttensioning also reduces the depth of spanning members and may be desirable where floor-to-floor heights must be kept to a minimum.

The extensive use of posttensioning in a concrete structure may limit the ease with which such a structure can be modified in the future, since penetrations in slabs and beams must not interrupt the continuity of the stressed cables or surrounding concrete. This may make posttensioning an undesirable choice for buildings where significant change in program or structure is anticipated.

## ARCHITECTURAL SITECAST CONCRETE CONSTRUCTION

The inherent fire-resistive qualities of concrete construction allow concrete systems to remain exposed in completed buildings even of significant size. The process by which concrete is formed on-site, and its monolithic and plastic qualities as a finished product, also give this material unique architectural possibilities.

When designing exposed *architectural concrete*, the choice of system will have a significant impact on the building design and aesthetic and should be considered as early as possible in the design process. Factors to consider include the added cost and difficulty of achieving high levels of finish quality and dimensional accuracy with concrete, the absence of hollow spaces for the routing of concealed mechanical and electrical services, and the potential aesthetic qualities of the various construction elements and systems.

## CONCRETE STRENGTH AND COLUMN SIZE

The top chart on the facing page is based on 4000 psi (25 MPa) concrete with reinforcing appropriate for buildings of low to moderate height. For taller buildings or longer-span systems, the larger column sizes indicated may become uneconomical due to the increasing quantity and weight of materials required, as well as the greater encroachment on usable floor area. In these circumstances, higher-strength concrete and greater amounts of reinforcing can be used to maintain columns of more practical size. To adjust the column size in the top chart on the facing page for variations in concrete strength, use the factors in the table to the right.

| Concrete Strength | | Multiply Column Size by: |
|---|---|---|
| 6000 psi | (40 MPa) | 0.80 |
| 8000 psi | (48 MPa) | 0.70 |
| 12,000 psi | (85 MPa) | 0.60 |
| 16,000 psi | (110 MPa) | 0.50 |

## MINIMUM COLUMN SIZES

Square concrete columns should not be less than 10 in. (250 mm) on each side. Rectangular columns should not be less than 8 × 10 in. (200 × 250 mm), with the wider side never more than three times the width of the shorter side. Round columns should not be less than 12 in. (150 mm) in diameter.

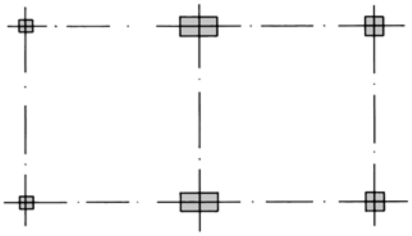
For columns used with any of the two-way slab systems listed in the table to the right, see the pages indicated for additional limits on minimum column size in relation to the depth of the slab.

| Systems | Pages |
|---|---|
| Sitecast Concrete Two-Way Flat Plate | 118–119 |
| Sitecast Concrete Two-Way Flat Slab | 120–121 |
| Sitecast Concrete Waffle Slab | 122–123 |

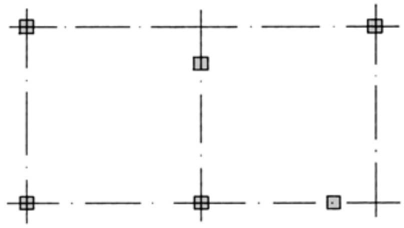
## ECONOMICAL CONCRETE COLUMN DESIGN

Column sizes should change as little as possible throughout a building. Where loads vary, column size can be held constant while its load capacity is varied by adjusting the strength of the concrete mix or the amount of steel reinforcing. In multistory buildings, column sizes should generally not vary between floors. Rather, higher-strength concrete or greater quantities of reinforcing are used in lower-story columns to compensate for the larger loads on those columns. Where size variations cannot be avoided, changing only one dimension of a column at a time, in multiples of 2-in. (50-mm) increments, is preferred.

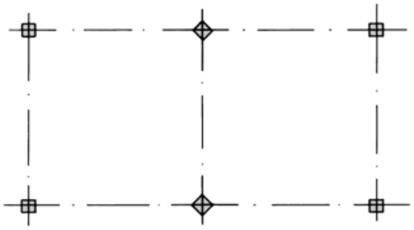
Columns should be as uniformly spaced as possible. Irregular column placements make formwork more expensive. Rectangular or square columns should conform to standard orthogonal alignments. Deviations from the normal complicate formwork where the column and the slab meet. See the diagrams to the right.



VARIATIONS IN COLUMN SIZE



VARIATIONS IN COLUMN PLACEMENT

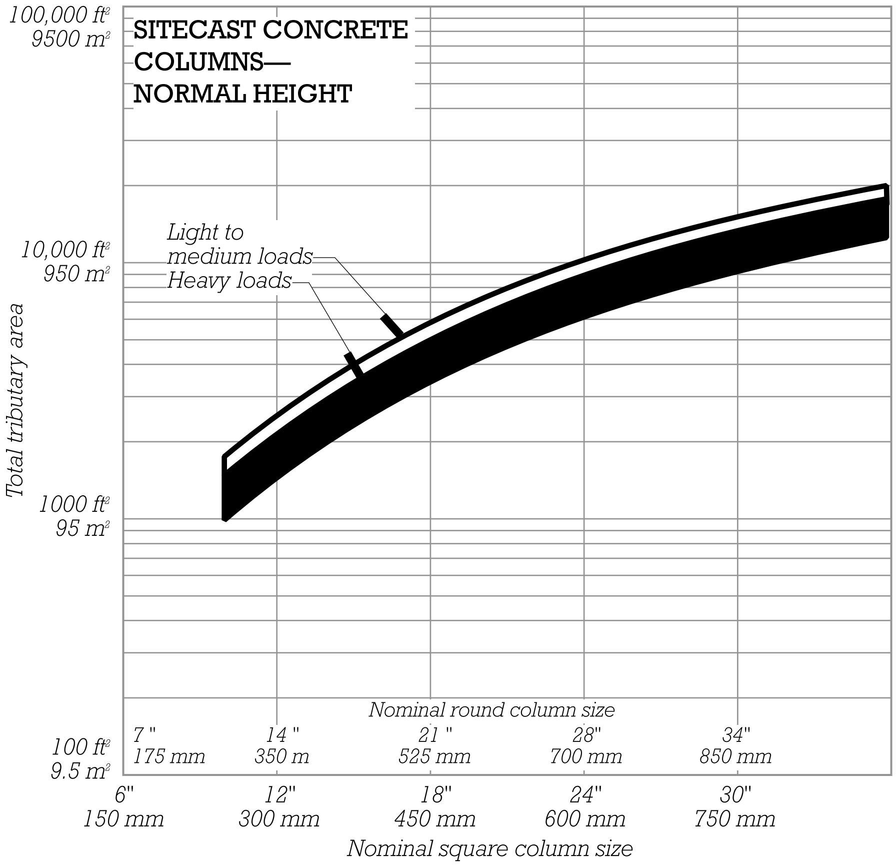


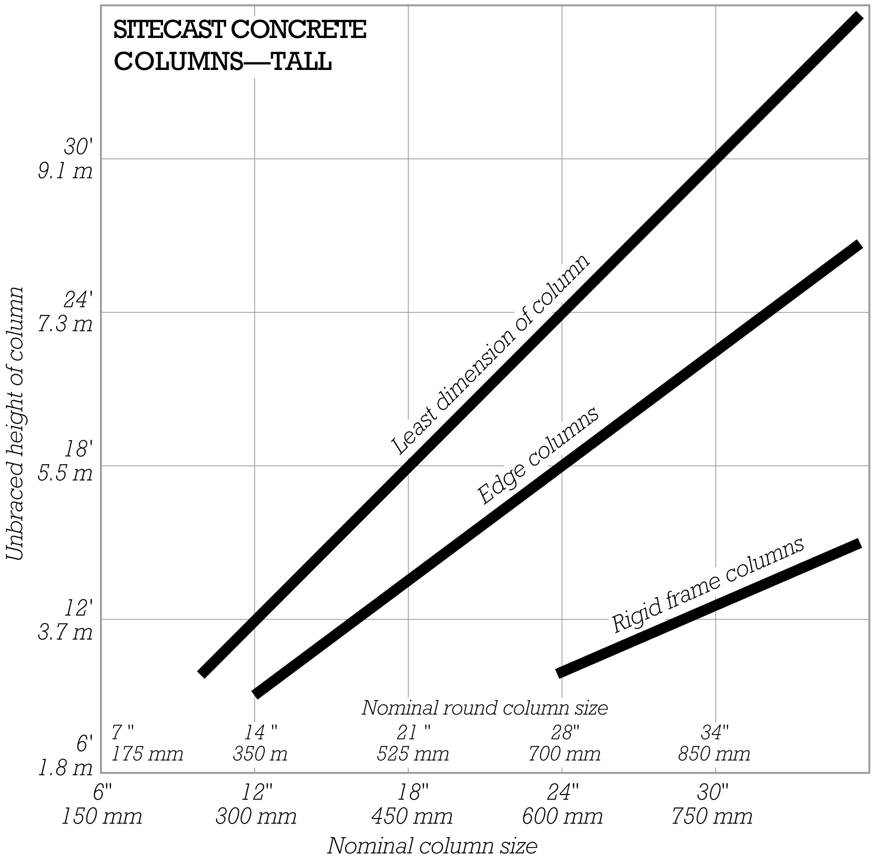
VARIATIONS IN COLUMN ALIGNMENT

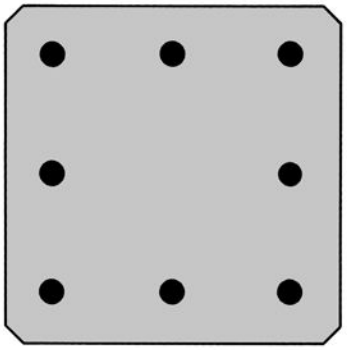
## FIRE-RESISTANCE RATINGS FOR SITECAST CONCRETE COLUMNS

Sitecast concrete columns may be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the placement of reinforcing. For preliminary design, you may assume that a 1-hour fire-resistance rating can be achieved with columns not less than 8 in. (200 mm) on a side. Fire-resistance ratings of 2, 3, and 4 hours can be achieved with columns 10 in. (250 mm), 12 in. (300 mm), and 14 in. (350 mm) in minimum dimension, respectively.

# SITECAST CONCRETE COLUMNS







The top chart is for sitecast concrete columns with a clear height of up to 10 ft (3.0 m). Clear height is the distance from the top of the slab below the column to the underside of the slab or beam above. For light to medium loaded columns, read in the upper open area of the curve. For heavily loaded columns, read in the lower solid area. *Total tributary area* is the summed area of the roof and all floors supported by the column.

- For rectangular columns, select a column of area equal to the square size indicated.
- Actual column size is equal to nominal size.

For columns with a clear height greater than 10 ft (3.0 m), read from both charts on this page, using the larger size indicated by either one. First, read along the line labeled *Least dimension of column* to determine the smallest permitted size. Columns subject to high bending forces are further restricted as follows: For those that are part of a rigid frame lateral force resisting system, the column's minimum size in the direction to which it is subject to bending is indicated by the line labeled *Rigid frame columns*. For columns located close to the edge of the slab it supports (within one-quarter of a span or less), the column's minimum size perpendicular to the slab edge is indicated by the line labeled *Edge columns*.

Sitecast concrete bearing walls may be used as the primary loadbearing element in a structural system or may be an integrated part of many other systems. Some of the most common uses for concrete walls include construction below grade, building structural cores, and shear walls in steel or concrete frame construction.

## CONCRETE STRENGTH AND WIDTH OF WALL

The top chart on the facing page is based on 4000 psi (25 MPa) concrete with reinforcing levels appropriate for buildings of low to moderate height. For taller buildings or longer-span systems, the wider wall sizes indicated may become uneconomical due to the increasing quantity and weight of materials required, as well as the greater encroachment on usable floor area. In these circumstances, higher-strength concrete can be used to maintain walls of more practical size. To adjust the width of walls in the top chart on the facing page for variations in concrete strength, use the factors in the table to the right.

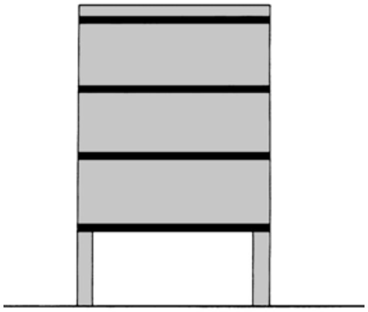
| **Concrete Strength** | **Multiply Width of Wall by** |
|---|---|
| 6000 psi (40 MPa) | 0.80 |
| 8000 psi (55 MPa) | 0.65 |
| 12,000 psi (85 MPa) | 0.45 |
| 16,000 psi (100 MPa) | 0.35 |

## DESIGN OF SITECAST CONCRETE WALLS

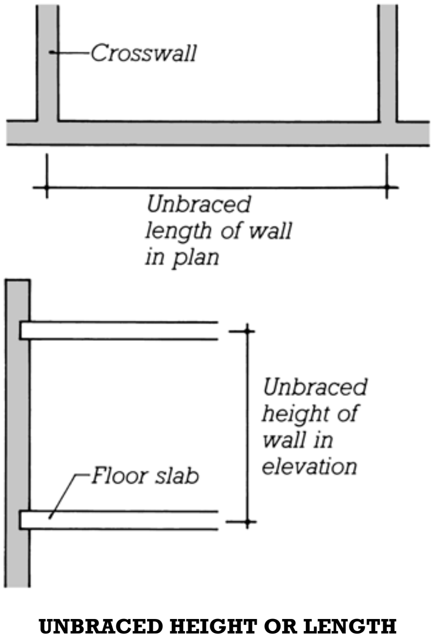
Nonloadbearing walls may be as thin as 4 in. (100 mm). Loadbearing sitecast concrete walls 6 in. (150 mm) wide should be used for light loads and one-story structures only. Loadbearing walls 8 in. (200 mm) wide are suitable for low-rise structures and light to medium loads. For taller structures and heavy loads, use concrete walls 10 in. (250 mm) or wider. Vary wall thickness as little as possible. Where necessary, changes in thickness should be in 2- or 4-in. (50- or 100-mm) increments.

Loadbearing wall locations should be consistent from floor to floor and continuous to the building foundation. Where it is desirable to omit bearing walls on a lower floor, an economical alternative may be to design the wall above to act as a deep beam spanning between columns at each end. The space between columns may then remain open. Such wall beams may economically span to 20 to 30 ft (6 to 9 m).

Sitecast concrete walls are frequently used as shear walls to help stabilize buildings against wind and seismic forces. The guidelines for minimum widths of walls provided on these two facing pages should normally result in walls with sufficient capacity to also act as shear walls where required. In addition, conventional concrete shear walls should be proportioned so that their total height, from foundation to top of wall, is no more than four times the length of the wall. Nevertheless, with special design, taller, more slender walls are also practical. For more information on designing building lateral stability systems, see pages 39–40.



***Bearing walls may act as deep beams to span across openings below.***

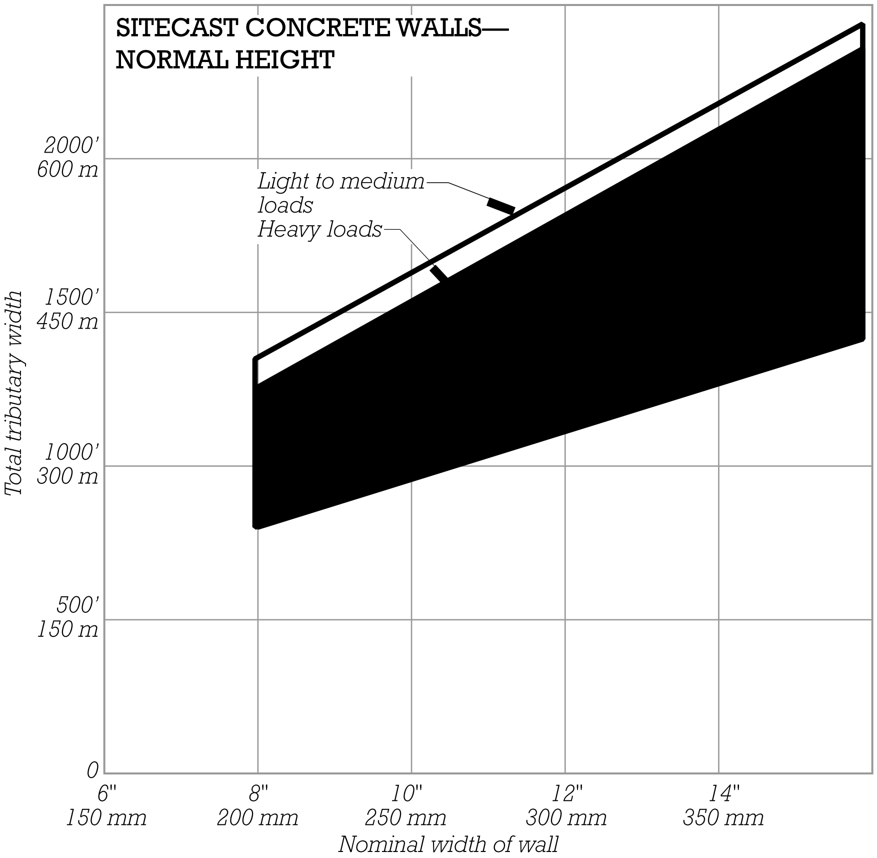


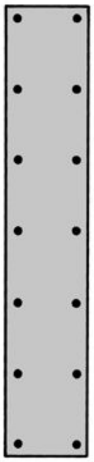
**UNBRACED HEIGHT OR LENGTH OF CONCRETE WALLS**

## FIRE-RESISTANCE RATINGS FOR SITECAST CONCRETE WALLS

Sitecast concrete walls may be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the placement of reinforcing. For preliminary design, assume that a 1-hour fire-resistance rating can be achieved with a wall 4 in. (100 mm) in width. Fire-resistance ratings of 2, 3, and 4 hours can be achieved with walls 5 in. (125 mm), 6 in. (150 mm), and 7 in. (175 mm) in width, respectively.

# SITECAST CONCRETE WALLS



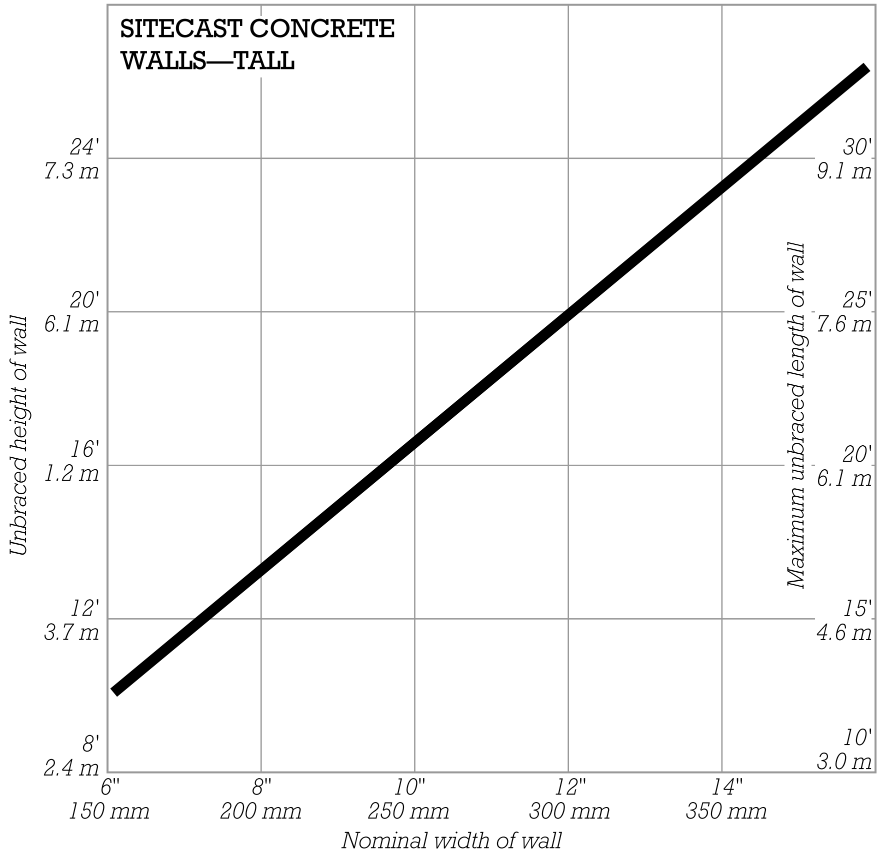


The top chart is for sitecast concrete walls up to 10 ft (3.0 m) tall between floors. For light loads, read in the upper open area of the curve. For medium to heavy loads, read in the lower solid area. *Total tributary width* is one-half the span of one floor supported by the wall multiplied by the number of floors and roof above.

- Actual width of the wall is equal to its nominal width.

For walls greater than 10 ft (3.0 m) in height, read from both charts on this page, using the larger size indicated by either chart. *Unbraced height of wall* is the vertical distance between floors or other supports that brace the wall laterally against buckling along the wall's vertical axis.

Use the lower chart to also check the *Maximum unbraced length of wall*, the maximum permissible length of the wall between crosswalls, pilasters, or other elements bracing the wall along its horizontal axis. (See the diagrams on the facing page.) Starting with the wall's nominal width, read up to the curve and then across to the scale on the right-hand side of the chart to determine the wall's maximum length between supports.



## ECONOMICAL BEAM DESIGN

Sitecast concrete is a versatile building material with unique expressive potential. While it can be used in a great variety of ways, for maximum economy, consider the following guidelines.

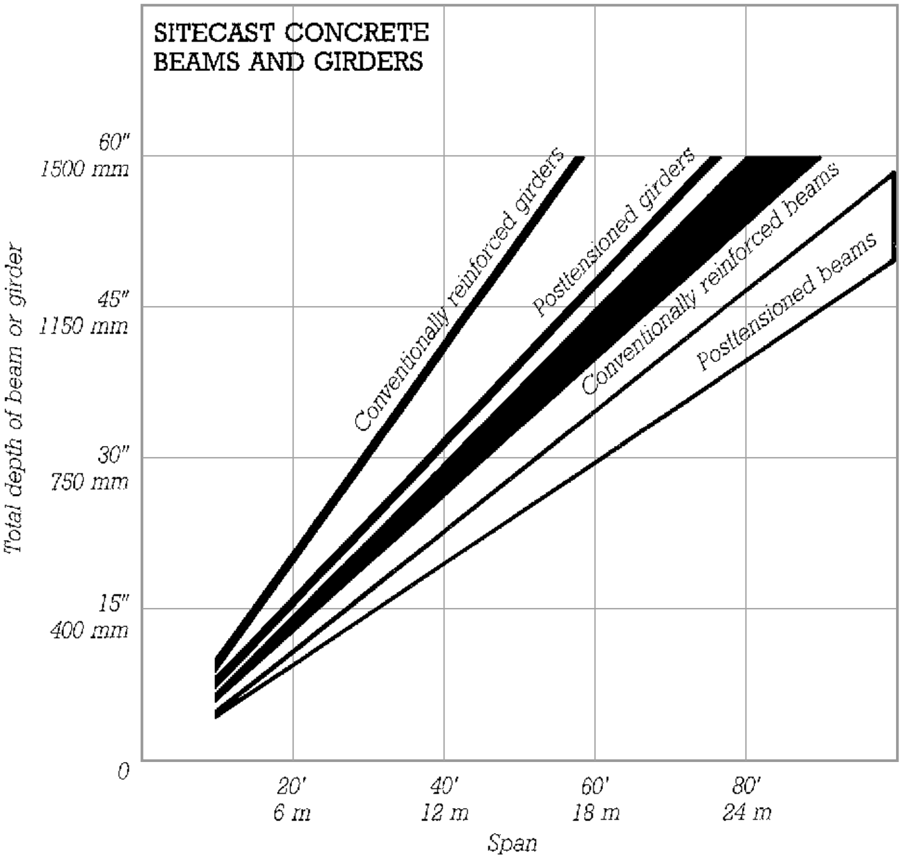
Maintain uniform sizes of beams throughout the building to the greatest extent possible. Size the beam with the longest span, using the chart on the facing page. Beams with shorter spans can often be the same size with reduced reinforcement. Use beam widths equal to or greater than the widths of the columns supporting them.

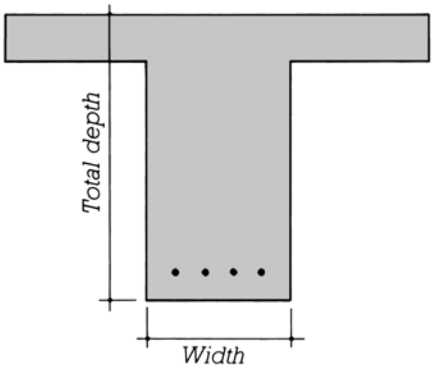
In some systems, an economical alternative to conventionally sized beams and girders is wide, shallow beams called *slab bands* (for solid slab construction) or *joist bands* (for one-way joist construction). Savings in floor-to-floor heights are possible with the reduced depth of beam, and formwork costs are reduced. The depth of the slab itself may be reduced as well, since with broader beams, the span of the slab between beams is lessened. See pages 114–115 for slab bands and pages 116–117 for joist bands.

## FIRE-RESISTANCE RATINGS FOR SITECAST CONCRETE BEAMS AND GIRDERS

Sitecast concrete beams and girders may be used in both Combustible and Noncombustible Construction. Their fire-resistance ratings vary with the composition of the concrete and the placement of reinforcing. For preliminary design, concrete beams and girders with a width of 10 in. (250 mm) may have an assumed fire-resistance rating of 4 hours.

# SITECAST CONCRETE BEAMS AND GIRDERS





This chart is for sitecast concrete beams and girders, either conventionally reinforced or posttensioned. For lightly to moderately loaded beams, read toward the right in the indicated areas. For heavy loads, read toward the left. For simple-span beams (those spanning between only two columns rather than between three or more columns), also read toward the left.

■ For girders, read on the lines indicated.

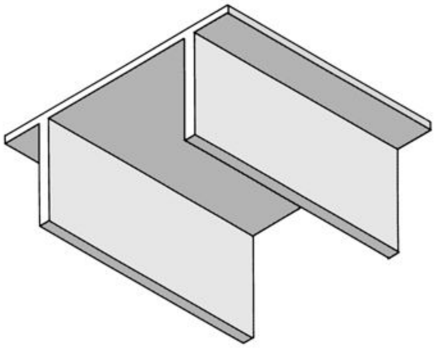
■ Size beam depths in even 2-in. (50-mm) increments.

■ *Total depth of beam or girder* is measured from the bottom of the beam to the top of the slab.

■ Normal beam widths range from one-third to one-half of the beam depth. Use beam widths in multiples of 2 or 3 in. (50 or 75 mm).

# SITECAST CONCRETE ONE-WAY SOLID SLAB

One-way solid slab construction supported by bearing walls is the least expensive sitecast concrete framing system for short spans and light loads. It is a popular concrete construction system for multiple dwelling building types such as apartments or hotels, where the regular spacing of bearing walls is easily coordinated with the layout of the small, uniformly arranged rooms typical of these buildings.



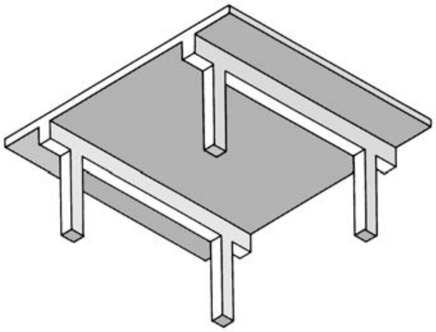
**ONE-WAY SOLID SLAB WITH BEARING WALLS**

## ONE-WAY BEAM AND SLAB SYSTEMS

The addition of beams and girders to one-way solid slab construction can increase the load capacity and span range of the system and eliminate the need for regularly spaced walls in the building plan. However, with the increased complexity of beam and girder formwork, the beam and slab system is one of the most expensive of all sitecast concrete systems. One-way beam and slab construction is usually economical only where long spans or high loads must be accommodated, such as with industrial uses or in areas of high seismic risk.

Slab bands can be an economical alternative to conventional deeper beams when beams are used. Savings in floor-to-floor heights are possible with the reduced beam depths, and formwork costs are reduced. The depth of the slab itself may be reduced as well, since with the broader beams, the span of the slab between the beams is lessened.

Maximum repetition of standard sizes increases the economy of slab and beam systems. Wherever possible, beam depths should be sized for the longest spans, and then the same depths should be used throughout. Beam widths and spacings, slab depths, and column sizes and spacings should all vary as little as possible within the structure.

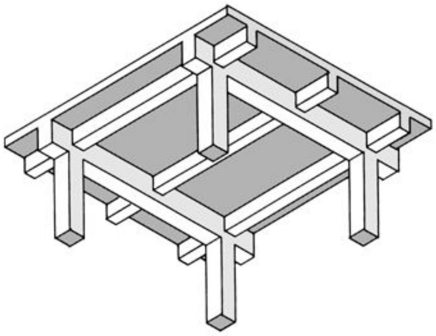


**ONE-WAY SOLID SLAB WITH BEAMS**

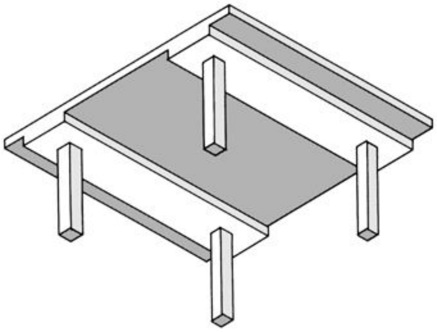
## FIRE-RESISTANCE RATINGS FOR ONE-WAY SOLID SLAB CONSTRUCTION

Sitecast concrete one-way solid slabs may be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the placement of reinforcing. Use the following guidelines for preliminary design:

To achieve a 3-hour fire-resistance rating, a solid slab must be at least 6.5 in. (165 mm) thick. For a 2-hour rating, the minimum thickness is 5 in. (127 mm); for 1½ hours, 4.5 in. (114 mm); and for 1 hour, 3.5 in. (89 mm).

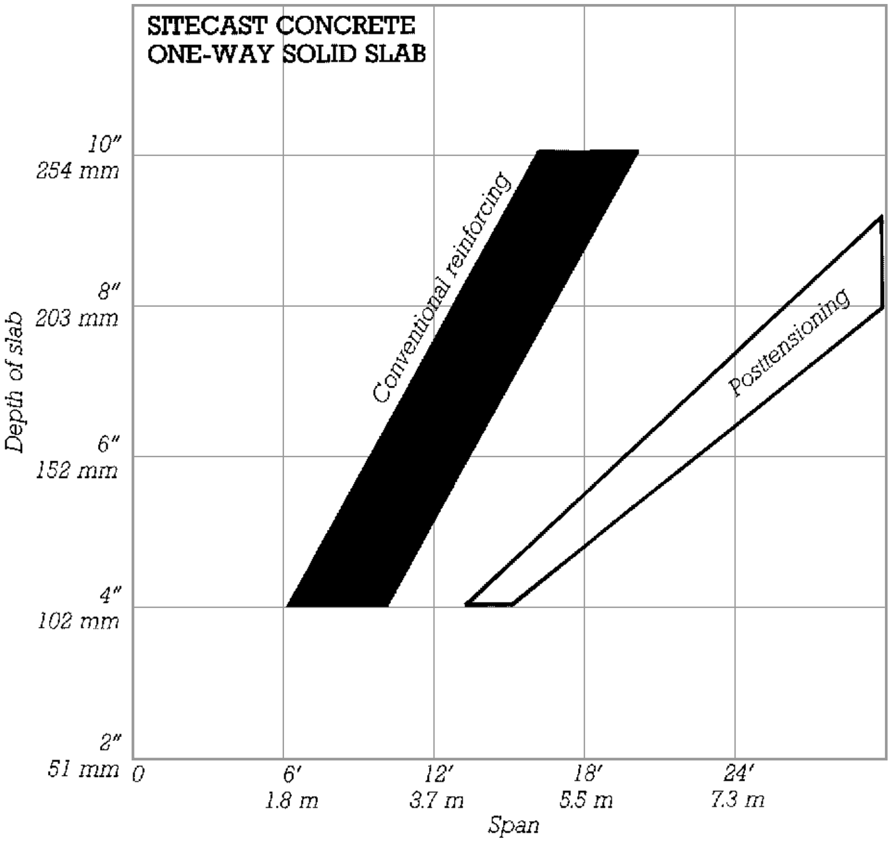


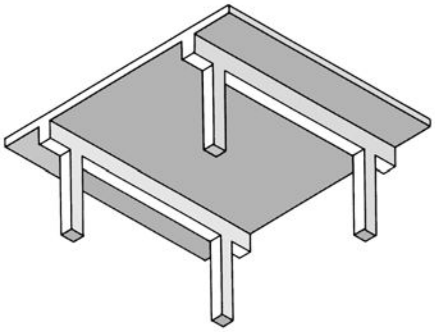
**ONE-WAY SOLID SLAB WITH BEAMS AND GIRDERS**



**ONE-WAY SOLID SLAB WITH SLAB BANDS**

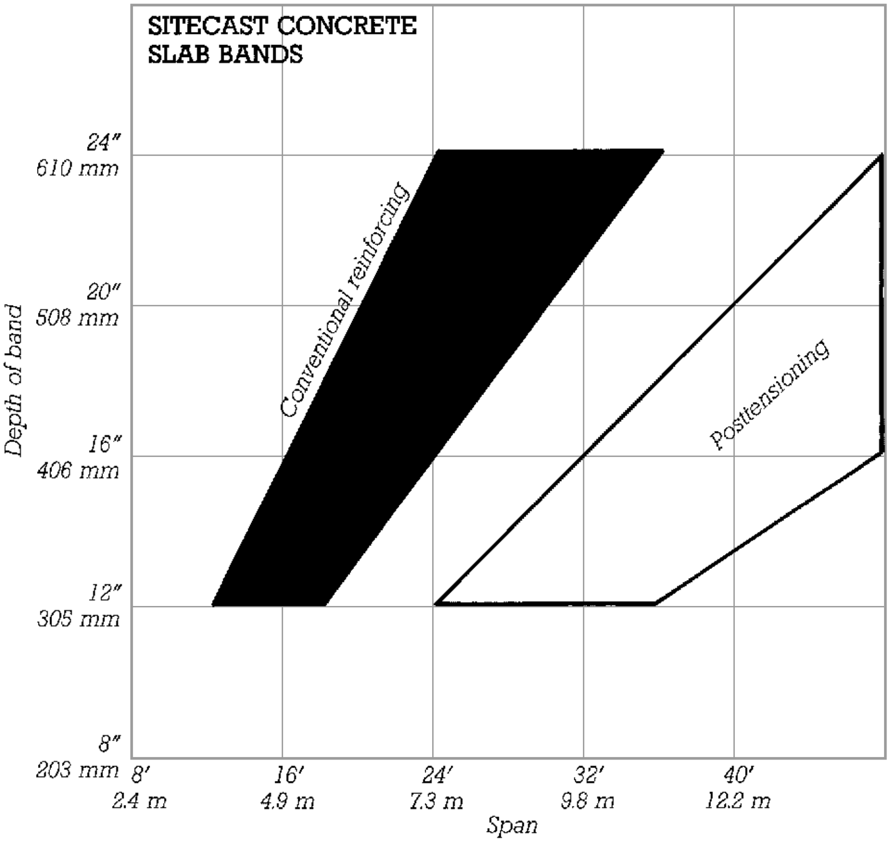
# SITECAST CONCRETE ONE-WAY SOLID SLAB

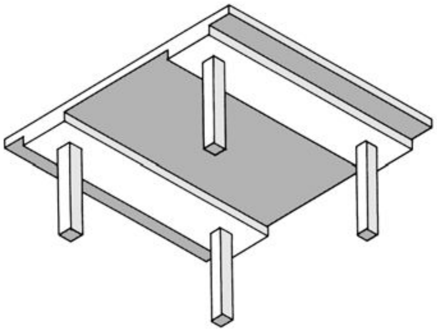




The top chart is for sitecast concrete one-way solid slab construction, either conventionally reinforced or posttensioned. For light to medium loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- ■ Size slab depth up to the nearest ½ in. (10 mm).
- ■ For the sizing of concrete beams, see pages 112–113.





The bottom chart is for concrete slab bands—deep, wide beams that can be used with one-way solid slab construction. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- ■ Size beam depths to the nearest inch (25 mm) and widths to the nearest foot (300 mm).
- ■ Typical widths for slab bands range from one-sixth to one-third of the span of the slab between the beams. For slab bands that are relatively deep or that span short distances, choose a narrow width. For slab bands that are relatively shallow or that span long distances, choose a wider width.

## SITECAST CONCRETE ONE-WAY JOISTS

One-way joist construction is an economical system for heavy loads or relatively long spans. This system is also sometimes desirable for the distinctive appearance of the underside of the slab, which may be left exposed in finished construction.

### JOIST LAYOUT

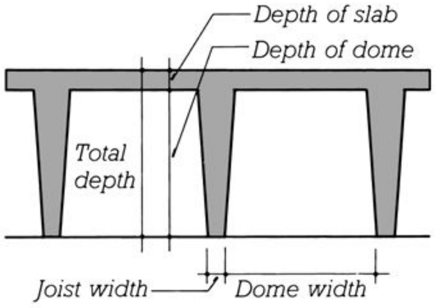
The spacing of joists depends on the widths of the pans and the joists. Standard pan widths are 20 and 30 in. (508 and 762 mm). Joists typically range in width from 5 to 9 in. (127 to 229 mm). A 6-in. (152-mm)-wide joist may be assumed for preliminary purposes.

In medium- and light-load applications, alternate joists may be omitted for greater economy. This system, called *wide module* or *skip joist* construction, is economical for spans of up to approximately 40 ft (12 m). In some instances, joist spacing may be increased to as much as 9 ft (2.7 m).

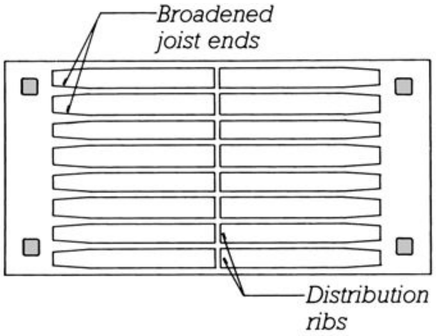
In long-span or heavy-load applications, joists may be broadened 2 to 2½ in. (50 to 65 mm) over the last 3 ft (1 m) toward their ends for increased shear capacity.

For joist spans of greater than 20 ft (6.1 m), distribution ribs running perpendicular to the joists are required. These ribs are 4 in. (102 mm) wide and the same depth as the joists. For longer spans, allow a maximum of 15 ft (4.6 m) between evenly spaced lines of ribs.

The economy of this system depends on the maximum repetition of standard forms and sizes. Depths, thicknesses, and spacings should vary as little as possible.



**ONE-WAY JOISTS**

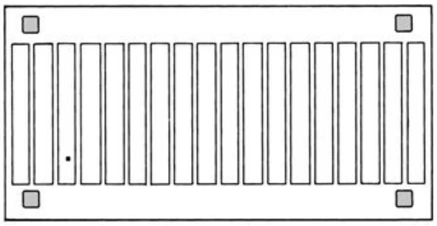


***Joist bands usually run the shorter direction in rectangular bays.***

### JOIST BANDS

The use of joist bands the same depth as the joists is a highly economical alternative to conventional deeper beams. This system reduces building height, speeds construction, and simplifies the installation of building utilities. In some instances, it may even prove economical to use a joist system deeper than otherwise necessary in order to match the required depth of the joist bands.

With rectangular column bays and normal to heavy loads, joist bands should usually run in the shorter direction.



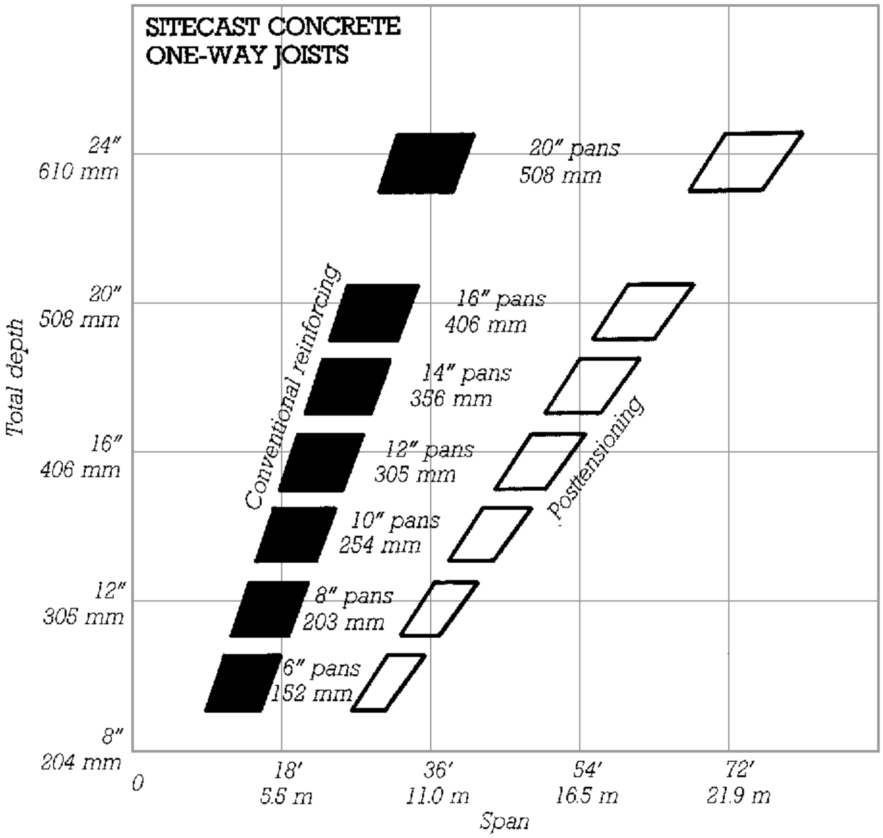
***With light loads, it may be more economical to run joist bands in the long direction in a rectangular bay.***

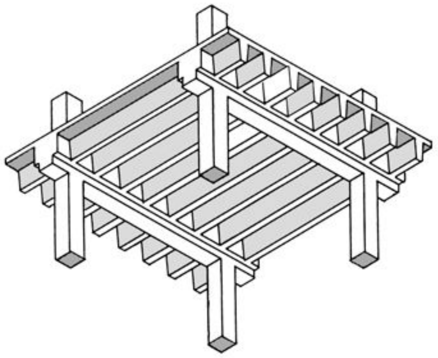
### FIRE-RESISTANCE RATINGS FOR ONE-WAY JOIST CONSTRUCTION

Sitecast concrete one-way joists may be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the placement of reinforcing. Use the following guidelines for preliminary design:

A slab that is 3 in. (76 mm) deep between joists has a fire-resistance rating of 0 to 1½ hours. A 4½-in. (114-mm)-deep slab provides 1½ to 3 hours of fire protection. For higher fire-resistance ratings, the slab thickness may be increased, fireproofing materials may be applied to the underside of the joists and slab, or an appropriately fire-resistive ceiling may be used.

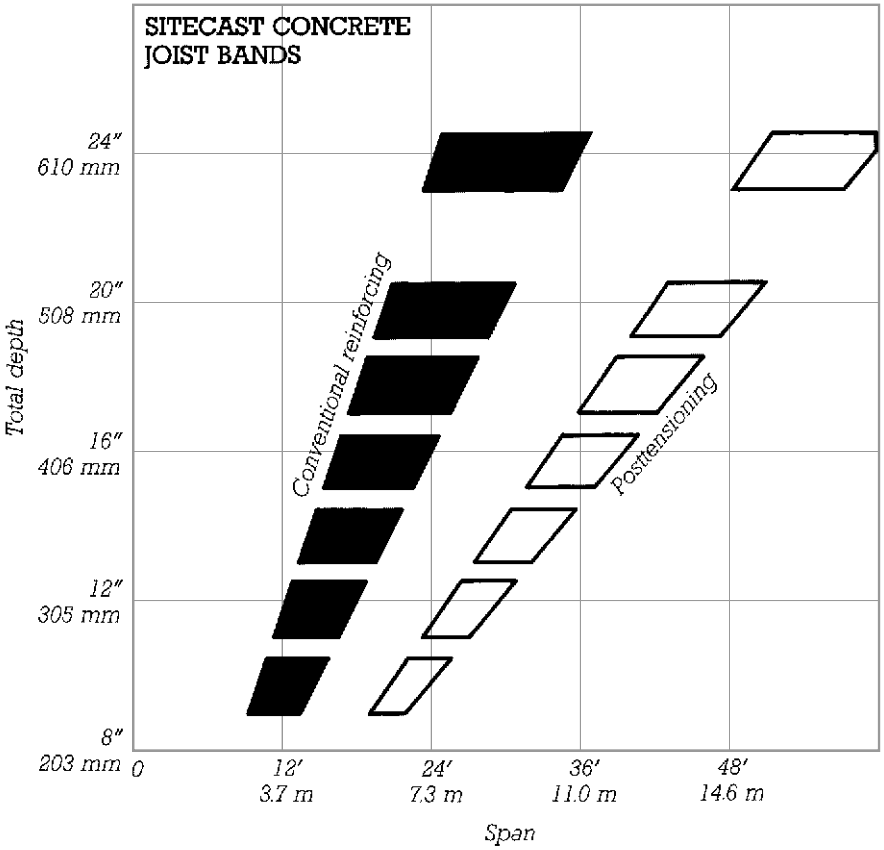
# SITECAST CONCRETE ONE-WAY JOISTS

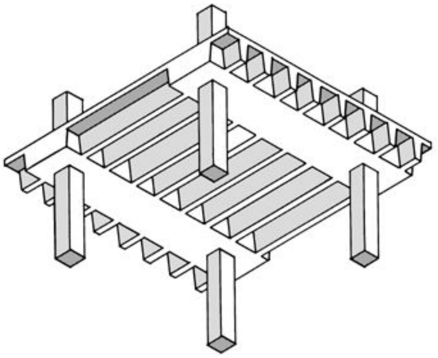




The top chart is for sitecast concrete one-way joist construction, either conventionally reinforced or posttensioned. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

■ *Total depth* is measured from the bottom of the joist to the top of the slab. (See the diagram on the facing page.) Depths are indicated on the chart for slabs of 3 to 4½ in. (76 to 114 mm) deep with standard pan sizes. The choice of the slab depth usually depends on the required fire-resistance rating for the system.





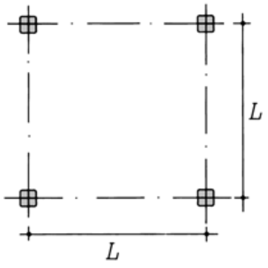
The bottom chart is for concrete joist bands—deep, wide beams used with the one-way joist system. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

■ For economy of formwork, use a joist band of the same depth as the joists.

■ Typical widths for joist bands range from 1 to 6 ft (0.3 to 1.8 m).

# SITECAST CONCRETE TWO-WAY FLAT PLATE

Two-way flat plate construction is one of the most economical concrete framing systems. This system can span farther than one-way slabs, and the plain form of the slab makes it simple to construct and easy to finish. This system is a popular choice, for example, for apartment and hotel construction, where it is well suited to the moderate live loads, and the flexibility of its column placements permits greater ease of unit planning and layout than with a one-way system.



**SQUARE BAYS**

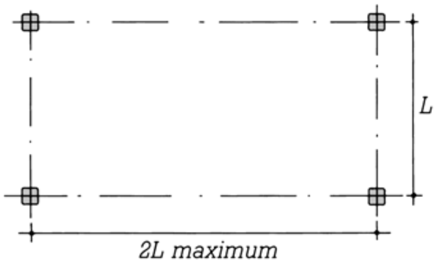
## COLUMN LAYOUTS FOR FLAT PLATE CONSTRUCTION

For maximum economy and efficiency of the two-way structural system, the following guidelines on column placement should be followed whenever possible:

Column bays are most efficient when square or close to square. When rectangular bays are used, the sides of the bays should differ in length by a ratio of no more than 2:1.

Individual columns may be offset by as much as one-tenth of the span from regular column lines. (Columns on floors above and below an offset column must also be equally offset to maintain a vertical alignment of columns.)

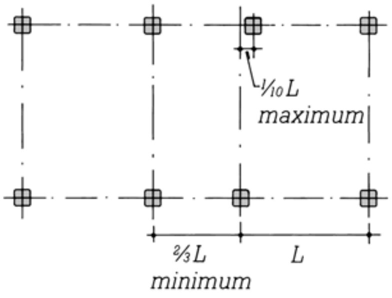
Successive span lengths should not differ by more than one-third of the longer span. Slabs should also span over at least three bays in each direction.



**RECTANGULAR BAYS**

## TWO-WAY SLAB AND BEAM CONSTRUCTION

Two-way slab and beam construction uses beams to support the slab between columns. The high construction costs of this system make it economical only for long spans and heavy loads, such as in heavy industrial applications, or where high resistance to lateral forces is required. For preliminary sizing of slab depths, read from the area for posttensioned construction in the chart on the facing page.

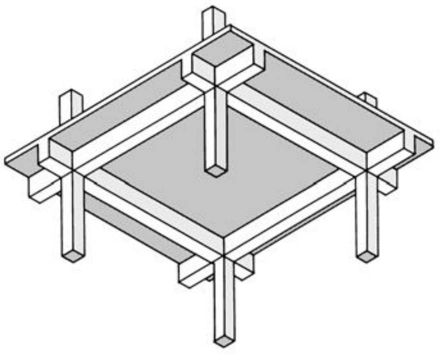


**COLUMN OFFSETS AND BAY SIZE VARIATIONS**

## FIRE-RESISTANCE RATINGS FOR TWO-WAY FLAT PLATE CONSTRUCTION

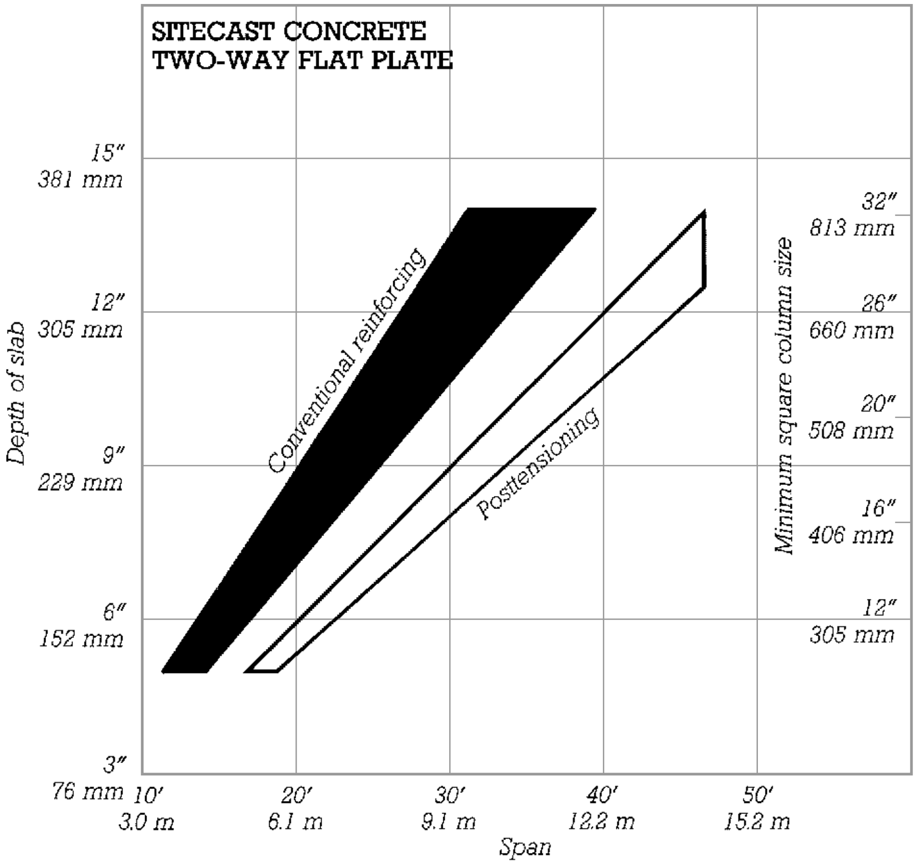
Sitecast concrete two-way flat plate construction may be used in both Combustible and Noncombustible Construction. Its fire resistance varies with the composition of the concrete and the placement of reinforcing. Use the following guidelines for preliminary design:

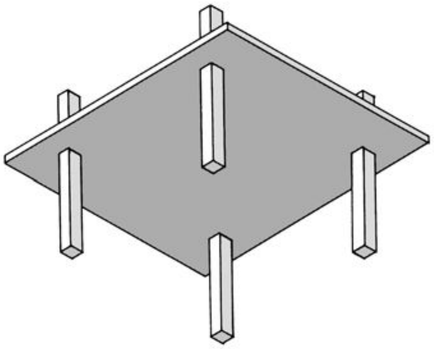
To achieve a 3-hour fire-resistance rating, the slab must be at least 6.5 in. (165 mm) thick. For a 2-hour rating, the minimum thickness is 5 in. (127 mm); for 1½ hours, 4.5 in. (114 mm); and for 1 hour, 3.5 in. (89 mm).



**TWO-WAY SLAB AND BEAM CONSTRUCTION**

# SITECAST CONCRETE TWO-WAY FLAT PLATE





This chart is for sitecast concrete flat plate construction, either conventionally reinforced or posttensioned. For medium to light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

■ For rectangular column bays, use the span of the longer of the two sides of the bay in reading from this chart.

■ Size slab depth to the nearest ½ in. (10 mm).

## COLUMN SIZES FOR FLAT PLATE CONSTRUCTION

The shallow depth of the junction between the slab and the column in flat plate construction restricts the minimum column size in this system. The right-hand scale on the chart above provides minimum square column sizes for various slab thicknesses. The required minimum column sizes for this system also depend on the applied loads on the structure. For light loads, reduce the indicated column size by 2 in. (50 mm). For heavy loads, increase the column size by 2 to 4 in. (50 to 100 mm).

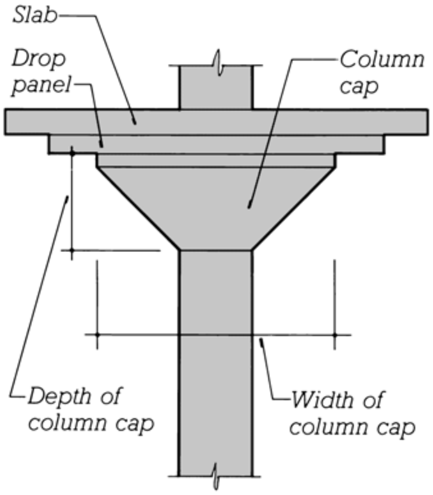
■ For rectangular columns, use a column whose area is equal to that of the square column indicated. For round columns, use a column diameter one-third greater than the square column size indicated. Column sizes may also need to be increased at the edges of a slab.

■ For columns in multistory buildings or for columns over 12 ft (3.7 m) tall, column size should also be checked using the charts on pages 108–109.

■ If smaller column sizes are desired, consider two-way flat slab construction as an alternative. See pages 120–121.

# SITECAST CONCRETE TWO-WAY FLAT SLAB

The two-way flat slab system is distinguished from flat plate construction by the strengthening of the column-to-slab junction, such as in the form of drop panels and/or column caps. Flat slab construction is an economical alternative to flat plate construction for heavier loads and longer spans. It also has increased resistance to lateral forces and, in some circumstances, may permit smaller columns than flat plate construction. However, the drop panels and column caps used in this system result in increased construction costs and greater overall floor depths than with flat plate construction.



**DROP PANELS AND COLUMN CAPS**

## DROP PANELS, COLUMN CAPS, AND SHEARHEADS

All flat slab construction requires some form of strengthening at the column-to-slab junction. Most commonly this is accomplished with the addition of *drop panels*, a deepening of the slab in the column region.

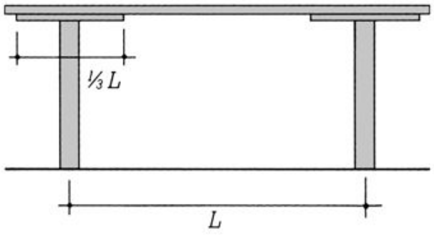
Alternatively, *column caps*, a widening of the columns toward their tops, may be used in place of drop panels where the loads on the slab are light or in conjunction with drop panels where loads are very high. Where all such formed elements are considered undesirable, special arrangements of steel reinforcing in the slab, termed *shearheads*, may be a feasible alternative to these methods.

The minimum size for drop panels is a width of one-third the span of the slab and a total depth of one and one-fourth times the depth of the slab. For heavy loads, greater panel sizes may be required.

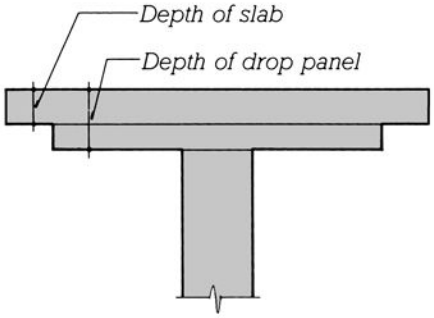
For maximum economy, keep all drop panels the same dimensions throughout the building. The difference in depth between the slab and the drop panels should be equal to a standard lumber dimension. The edges of drop panels should be a minimum of 16 ft 6 in. (5.0 m) apart to utilize standard 16-ft (4.9-m) lumber in the formwork.

When column caps are used, their overall width should be eight to ten times the slab depth. Column caps are commonly either tapered or rectangular in profile, but should be approximately half as deep as their width at the top.

The addition of beams to flat slab construction can increase the load capacity and span range of the system, though with increased costs.



**DROP PANEL WIDTH**



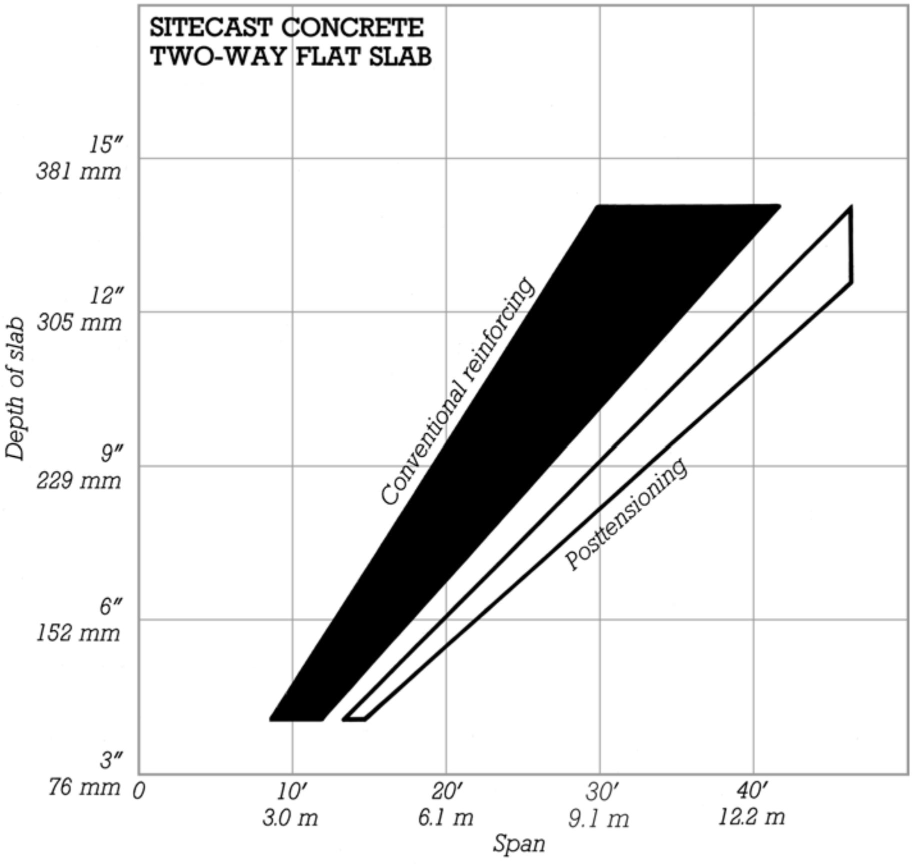
**DROP PANEL DEPTH**

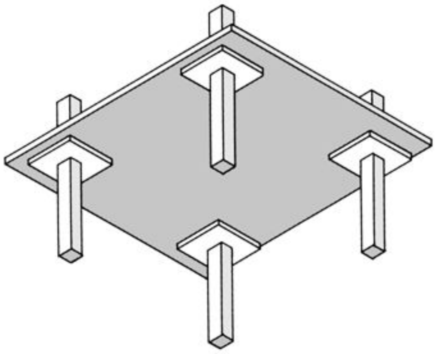
## FIRE-RESISTANCE RATINGS FOR TWO-WAY FLAT SLAB CONSTRUCTION

Sitecast concrete two-way flat plate construction may be used in both Combustible and Noncombustible Construction. Its fire resistance varies with the concrete composition and the placement of reinforcing. Use the following guidelines for preliminary design:

To achieve a 3-hour fire-resistance rating, the slab must be at least 6.5 in. (165 mm) thick. For a 2-hour rating, the minimum thickness is 5 in. (127 mm); for 1½ hours, 4.5 in. (114 mm); and for 1 hour, 3.5 in. (89 mm).

## SITECAST CONCRETE TWO-WAY FLAT SLAB





This chart is for concrete two-way flat slab construction, either conventionally reinforced or posttensioned. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- ■ For rectangular column bays, use the span of the longer of the two sides of the bay in reading from this chart.
- ■ Size slab depth to the nearest ½ in. (10 mm).

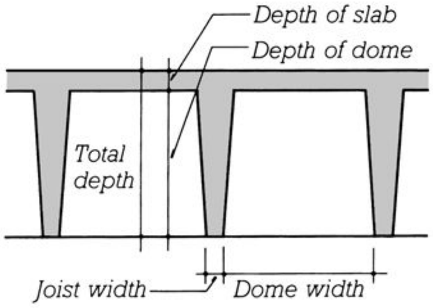
### COLUMN SIZES AND LAYOUTS FOR FLAT SLAB CONSTRUCTION

For light to moderate loads, use a minimum square column size of 12 in. (300 mm) for preliminary design. For heavier loads, larger columns or the addition of column caps may be required. Column size may be increased by 4 to 12 in. (100 to 300 mm) for extremely heavy loads.

For rectangular columns, use a column whose area is equal to that of the recommended square column size. For round columns, use a column diameter one-third greater than the recommended square column size. Column sizes may also need to be increased in multistory buildings or for columns taller than 12 ft (3.7 m). See pages 108–109 for checking column sizes for these conditions.

For maximum economy and efficiency of the two-way structural system, column layouts for flat slab construction should adhere to the same guidelines as those described for flat plate construction. Column bays should be approximately square, and column offsets from regular lines should be minimized. See page 118 for a complete discussion of these guidelines.

The concrete waffle slab (or two-way joist) system is best suited for long spans, heavy loads, and where a thicker floor system is not a disadvantage. It exhibits excellent vibration control, a consideration for some manufacturing and laboratory facilities. It may have economic advantages where concrete material costs are very high. And the underside of the waffle slab has a distinctive appearance that can be an architectural asset. However, the waffle slab also requires complex formwork to construct, making it a less favored choice where other, simpler sitecast concrete systems are feasible.



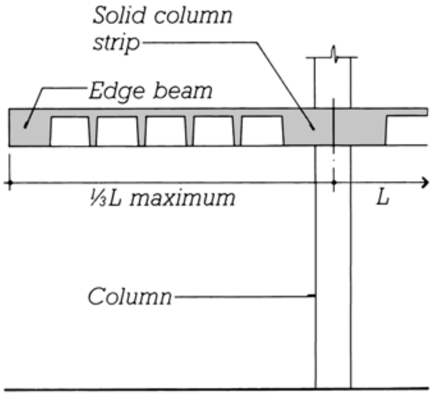
WAFFLE SLAB

## RIB LAYOUT FOR WAFFLE SLAB CONSTRUCTION

Standard 19-in. (483-mm) domes are used with ribs that are 5 in. (127 mm) wide to create a 24-in. (610-mm) module. Domes of 30 in. (762 mm) are used with 6-in. (152-mm) ribs to create a 36-in. (914-mm) module. Standard domes are also available for 4- and 5-ft (1.2- and 1.5-m) modules, and other square or rectangular sizes can be specially ordered.

Solid heads must be created over columns by omitting domes in the vicinity of each column and pouring the slab flush with the bottom of the ribs. The number of domes omitted varies, increasing with longer spans and heavier loads. In some cases, solid strips may extend continuously between columns in both directions.

The economy of this system depends on the maximum repetition of standard forms and sizes. Depths, thicknesses, and spacings should vary as little as possible.



EDGE BEAMS AND CANTILEVERS

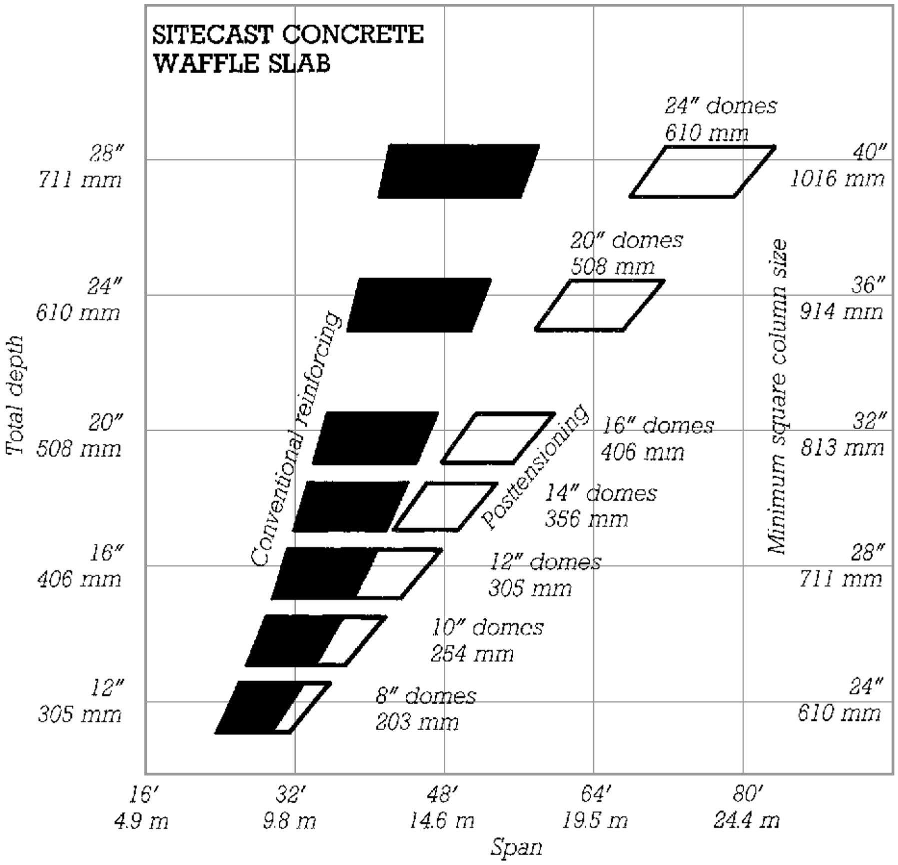
## EDGE CONDITIONS

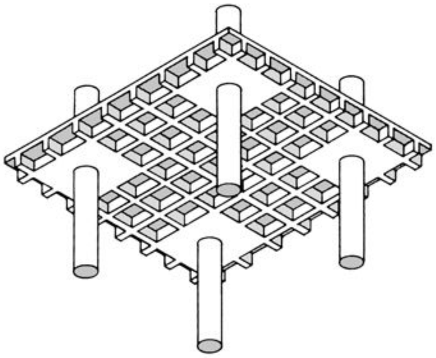
At waffle slab edges, the area between the outermost rib and the edge of the slab edge is filled solid to create an edge beam. Where the slab edge occurs over a line of columns, this edge beam runs column-to-column as a column strip. The slab may also cantilever beyond the columns by as much as one-third of a full span. In this case, both an edge beam and a solid strip running between the edge columns may be required.

## FIRE-RESISTANCE RATINGS FOR WAFFLE SLAB CONSTRUCTION

Sitecast concrete waffle slabs may be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the placement of reinforcing. Use the following guidelines for preliminary design:

A 3-in. (76-mm) slab thickness between ribs gives a fire-resistance rating of 0 to 1 hour. A 3½-in. (89-mm) thickness gives a rating of 1 hour, a 4½-in. (114-mm) thickness gives a rating of 1½ hours, and a 5-in. (127-mm) thickness gives a rating of 2 hours. For higher fire-resistance ratings, the slab thickness may be increased further, fireproofing materials may be applied to the underside of the ribs and slab, or an appropriately fire-resistive ceiling may be used.





This chart is for concrete waffle slab construction, either conventionally reinforced or posttensioned. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

■ For rectangular bays, use the average of the spans of the two sides of the bay when reading from this chart.

■ *Total depth* is the sum of the depth of the ribs and the slab. (See the diagram on the facing page.) Depths are indicated on the chart for slabs from 3 to 4½ in. (76 to 114 mm) deep with standard pan sizes. The choice of the slab depth usually depends on the required fire-resistance rating for the system. See the facing page for fire-resistance information.

## COLUMN SIZES AND LAYOUTS FOR WAFFLE SLAB CONSTRUCTION

In waffle slab construction, minimum column size is dependent on the overall thickness of the slab. The right-hand scale on the chart above provides minimum square column sizes for various slab thicknesses. For light loads, reduce the indicated column size by 2 to 4 in. (50 to 100 mm). For heavy loads, increase the indicated column size by 4 to 12 in. (100 to 300 mm).

For rectangular columns, use a column whose area is equal to that of the square column indicated. For round columns, use a column diameter one-third greater than the square column size indicated.

For columns in multistory buildings or for columns over 12 ft (3.7 m) tall, column size should also be checked using the charts on pages 108–109.

For maximum economy and efficiency of the two-way structural system, column layouts for waffle slab construction should adhere to the same guidelines as those described for flat plate construction. Column bays should be approximately square, and column offsets from regular lines should be minimized. See page 118 for a complete discussion of these guidelines.

# PRECAST CONCRETE STRUCTURAL SYSTEMS

Compared to sitecast concrete, precast prestressed concrete framing systems are characterized by reduced depths and deflections for spanning members, faster construction, and increased quality and durability of the concrete itself. Where future changes to a structure are anticipated, precast concrete may be a good choice due to the relative ease with which individual elements in the system can be removed or replaced. The difficulty of fabricating rigid joints in precast concrete structures leads to a greater reliance on shear walls or cross bracing to achieve lateral stability than in sitecast concrete structures and makes them potentially more sensitive to vibrations produced by heavy machinery or other sources. Precast concrete spanning elements are also often used in combination with other site-fabricated vertical loadbearing systems such as sitecast concrete, masonry, or steel.

## SELECTING A PRECAST CONCRETE FRAMING SYSTEM

The initial choice of a framing system should be based on the desired spanning capacity or column spacing of the system and the magnitude of the expected loads on the structure. The following precast concrete systems are listed in order of increasing spans, load capacity, and cost:

- Solid Flat Slab
- Hollow Core Slab
- Double Tee
- Single Tee

For short spans and light loads, select a system near the top of the list. For longer spans and heavier loads, systems toward the bottom of the list are required.

As with sitecast concrete, the inherent fire-resistive qualities of precast concrete construction allow these systems to remain wholly or partially exposed in the finished building. For this reason, the choice of a concrete framing system often has architectural implications that should be considered early in the design process. These include, for example, the absence of hollow spaces for the routing of concealed mechanical and electrical services, the possible use of the underside of the structural slab as a finish ceiling, and the aesthetic qualities of the system.

## LAYING OUT A PRECAST CONCRETE SYSTEM

The economy of precast concrete construction depends on the repetition of standard elements and sizes. Use the following guidelines for preliminary layout of a precast concrete structure to ensure maximum economy:

- In the direction of the span of the deck members, use a modular dimension of 1 ft (0.3 m). If a wall panel has been selected, use the width of the panel as the modular dimension.
- In the direction transverse to the span of the deck members, use a module of 8 ft (2.4 m). If a deck member has been selected, use the width of that member as the modular dimension.
- Floor-to-floor heights need not be designed to any particular module, though the maximum repetition of the dimension chosen is desirable. Where precast wall panels are used, floor-to-floor heights should be coordinated with the height of the wall panel.
- Restrictions due to shipping and handling of members usually limit span lengths to 60 to 80 ft (18 to 24 m). Further transportation restrictions on depths of elements usually limit bay widths to between 24 and 40 ft (7 and 12 m) where girders are used.

In general, any design features that require unique structural elements, excessive variations in the sizes of elements, alterations in structural configuration, or deviation from the standard dimensions of the system should be avoided. Where the maximum flexibility of layout with precast concrete elements is desired, solid flat slabs or hollow core slabs may be preferred over double or single tees for their shorter spans and the greater ease with which they may be sawn after casting to conform to irregular conditions.

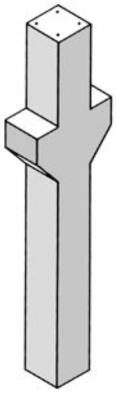
## PROJECT SIZE

The economy of precast concrete construction increases with the size of the construction project. The following figures are approximate minimum quantities for which the production of precast concrete elements may be economical:

- 10,000 sq ft (1000 $m^2$) of architectural wall panels, or
- 15,000 sq ft (1500 $m^2$) of deck or slab members, or
- 1000 linear feet (300 m) of girders, columns, or pilings.

Precast concrete columns are most commonly combined with precast beams in a post and beam configuration. Unlike sitecast concrete, where rigid or semirigid joints between columns and beams are easily made, in precast concrete framing such joints are more difficult to construct. For this reason, precast concrete framing systems most often rely on shear walls or braced framing for resistance to lateral forces.

Precast concrete columns are usually provided with conventional reinforcing. Prestressing may be used to reduce stresses on the columns during transportation and handling or to improve a column's resistance to anticipated bending forces in service.



PRECAST CONCRETE COLUMN WITH TWO CORBELS

### STANDARD SIZES AND SHAPES FOR PRECAST CONCRETE COLUMNS

Precast concrete columns are most commonly available in square profile in the sizes indicated on the charts on the facing page. Rectangular shapes can also be produced, although availability may vary with suppliers. For larger projects (requiring 1000 linear ft, or 300 m, or more of columns), economies of scale may make practical a greater range of sizes and configurations.

Columns up to approximately 60 ft (18 m) in length can be transported easily. Columns up to approximately 100 ft (30 m) in length may be shipped with special transportation arrangements.

For ease of casting, columns with corbels should be limited to corbels on two opposite sides or, at most, three sides.

Like all precast concrete elements, precast columns should be as consistent and regular as possible in dimensions and layout in order to achieve maximum economy.

## CONCRETE STRENGTH AND COLUMN SIZE

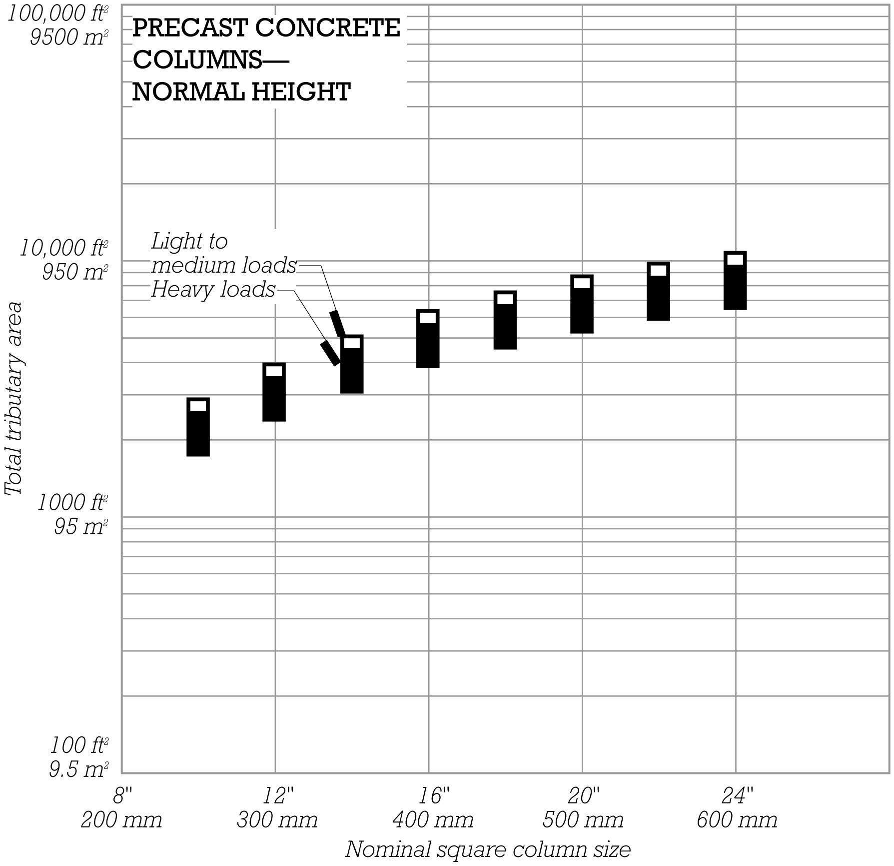
The top chart on the facing page is based on 5000 psi (35 MPa) concrete. Higher-strength concrete may also be used to reduce the required column size. To adjust the column sizes indicated in the top chart for variations in concrete strength, use the factors in the table to the right.

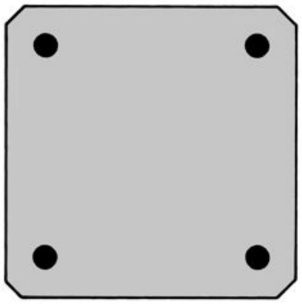
| Concrete Strength | | Multiply Column Size by |
|---|---|---|
| 6000 psi | (40 MPa) | 0.90 |
| 7000 psi | (50 MPa) | 0.85 |
| 8,000 psi | (55 MPa) | 0.80 |
| 10,000 psi | (70 MPa) | 0.70 |

## FIRE-RESISTANCE RATINGS FOR PRECAST CONCRETE COLUMNS

Precast concrete columns may be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the placement of reinforcing. For preliminary design, you may assume that a 2-hour fire-resistance rating can be achieved with columns not less than 10 in. (250 mm) on a side. Fire-resistance ratings of 3 and 4 hours can be achieved with columns 12 in. (300 mm) and 14 in. (350 mm) in the minimum dimension, respectively.

# PRECAST CONCRETE COLUMNS



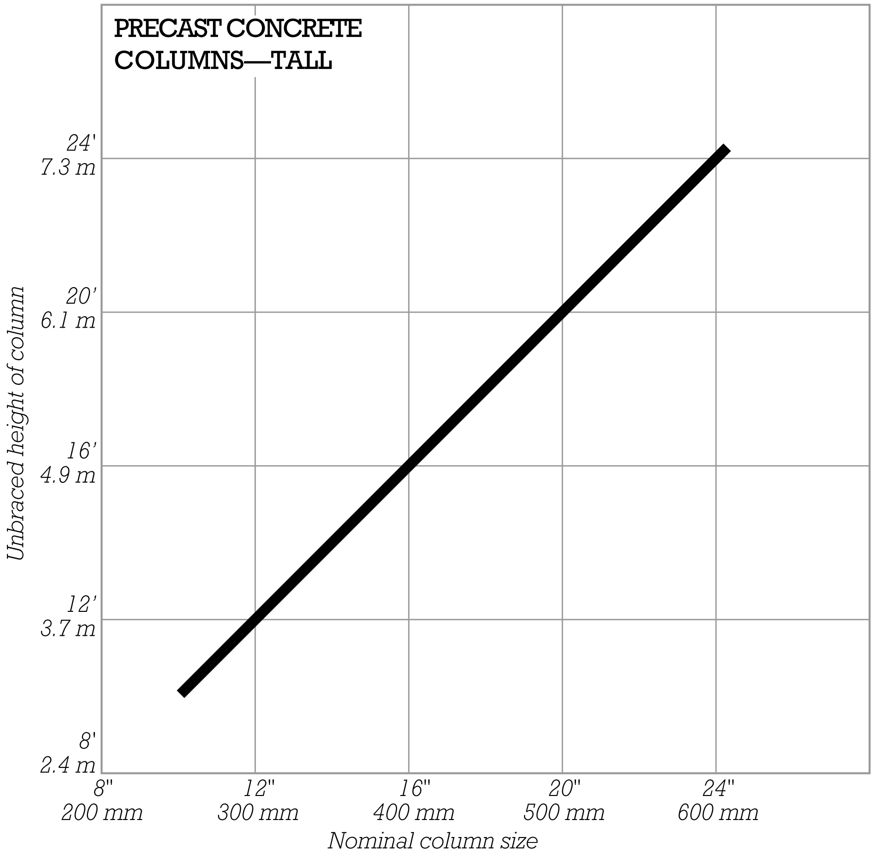


The top chart is for precast concrete columns up to 12 ft (3.7 m) tall between floors. For light to medium loads, read in the upper open areas of each bar. For high loads, read in the lower solid areas. *Total tributary area* is the summed area of the roof and all floors supported by the column.

- For rectangular columns, select a column of area equal to the square size indicated.
- Actual column size is equal to nominal size.

For columns taller than 12 ft (3.7 m), read from both charts on this page, using the larger size indicated by either one. *Unbraced height of column* is the vertical distance between floors or other supports that brace the column laterally against buckling.

- For rectangular columns, read the chart's nominal column size using the least dimension of the column.



# PRECAST CONCRETE WALL PANELS

There is great variety in precast concrete wall panel types for applications ranging from single-family residential buildings to tall commercial structures. Panels may be prestressed or conventionally reinforced; they may be loadbearing or nonbearing; they may or may not contribute to the lateral stability of a building; they may be flat, ribbed, or more intricately shaped; and they may be solid, hollow, or a sandwich of concrete with an insulating core. Precast concrete wall panels may be used in conjunction with a precast concrete framing system or with other framing systems, such as steel or concrete.

## PANEL TYPES

Flat panels may be one to two stories high. Ribbed panels may be up to four stories high.

Wall panels may also be formed in a great variety of unique shapes. The design of such panels depends on knowledge of precasting methods. When the use of such panels is planned, the necessary consultants or suppliers should be sought out early in the design process. For the preliminary sizing of such panels, use the chart for ribbed panels on the facing page. Such loadbearing wall panels may be used in buildings up to approximately 16 to 20 stories in height.

Panels with openings usually are not prestressed. Panels without openings may be prestressed to reduce thickness or to limit stresses in the panels during transportation and handling.

## SIZES OF PRECAST CONCRETE WALL PANELS

Solid panels are commonly available in thicknesses of 3½ to 10 in. (89 to 254 mm). Sandwich or hollow core panels range in thickness from 5½ to 12 in. (140 to 305 mm). Ribbed wall panels are commonly available in thicknesses of 12 to 24 in. (305 to 610 mm).

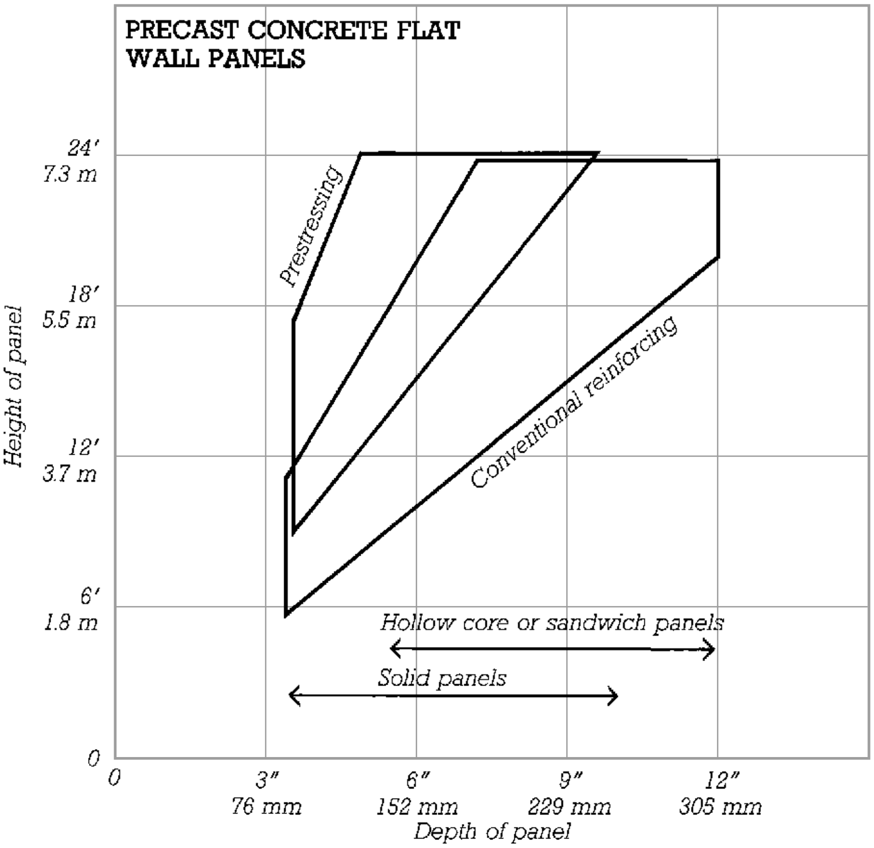
For preliminary design, assume an 8-ft (2.4-m) width for all panel types. With special provisions, panels in widths of up to approximately 14 ft (4.3 m) may be transported without excessive economic penalty.

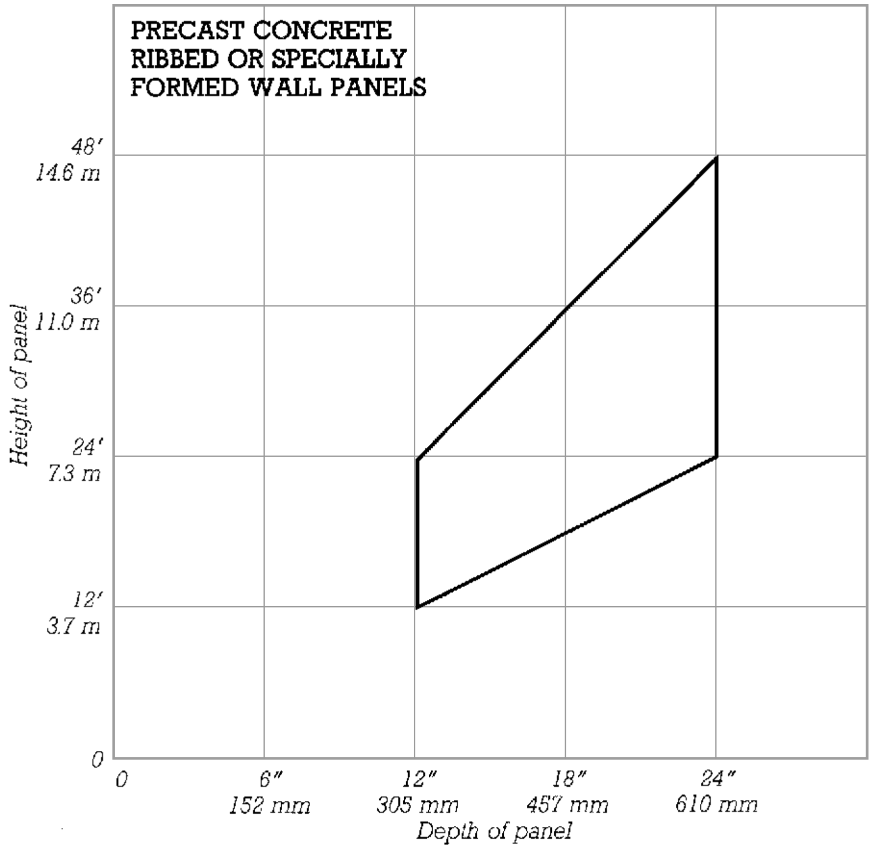
## FIRE-RESISTANCE RATINGS FOR PRECAST CONCRETE WALL PANELS

Precast concrete wall panels may be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the type and placement of reinforcing. In sandwich panels, core insulation influences fire resistance as well. The following guidelines may be used for preliminary design:

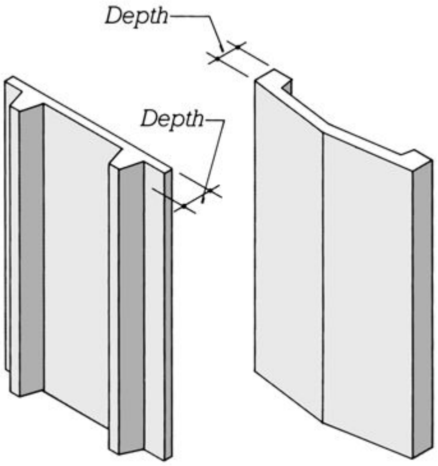
Panels must be at least 6.5 in. (165 mm) thick to achieve a fire-resistance rating of 4 hours. A 3-hour rating is achieved at a thickness of 6 in. (152 mm), a 2-hour rating at 5 in. (127 mm), and a 1-hour rating at 3.5 in. (89 mm).

# PRECAST CONCRETE WALL PANELS





The top chart is for flat precast concrete wall panels, either prestressed or conventionally reinforced. For nonbearing panels, read toward the left in the indicated areas. For loadbearing panels, read toward the right.



The bottom chart is for precast concrete wall panels formed with ribs, stems, or other stiffening features. For nonbearing or prestressed panels, read toward the left in the indicated area. For loadbearing panels, conventionally reinforced panels, or panels with integral window openings, read toward the right.

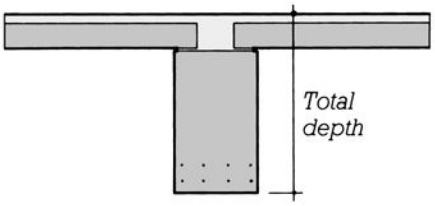
- *Depth of panel* is the total depth of the panel and any stiffening features.
- For the preliminary design of spandrel panels, use the distance between columns for the height indicated on either chart.

Precast prestressed concrete girders are commonly used to carry all varieties of precast concrete decking elements between columns or bearing walls. They can be used in any building type where precast concrete construction is to be considered.

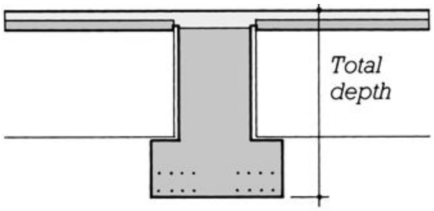
## TOTAL DEPTH OF FLOOR SYSTEMS

Rectangular beams are commonly used with solid or hollow core slabs resting on top of the beam. Total floor depth at the beam is the sum of the depths of the slab, the topping if any, and the beam.

Inverted T- and L-beams are commonly used with double and single tees. When they are erected, the top of the tees should be level with or slightly above the top of the beam. When the tees rest directly on the beam ledge, the total floor depth at the beam is the depth of the tee, the topping if any, and the depth of the ledge. Deeper tees may have their ends notched or "dapped" so as to rest lower on the beam. The use of dapped tees may result in total floor depths of as little as the depth of the tee itself plus any topping.



**RECTANGULAR BEAM WITH SOLID OR HOLLOW CORE SLABS**

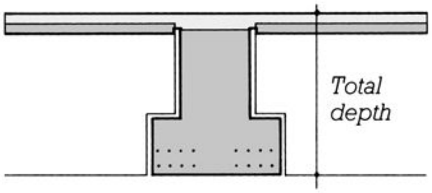


**INVERTED T-BEAM WITH SINGLE OR DOUBLE TEES**

## FIRE-RESISTANCE RATINGS FOR PRECAST BEAMS AND GIRDERS

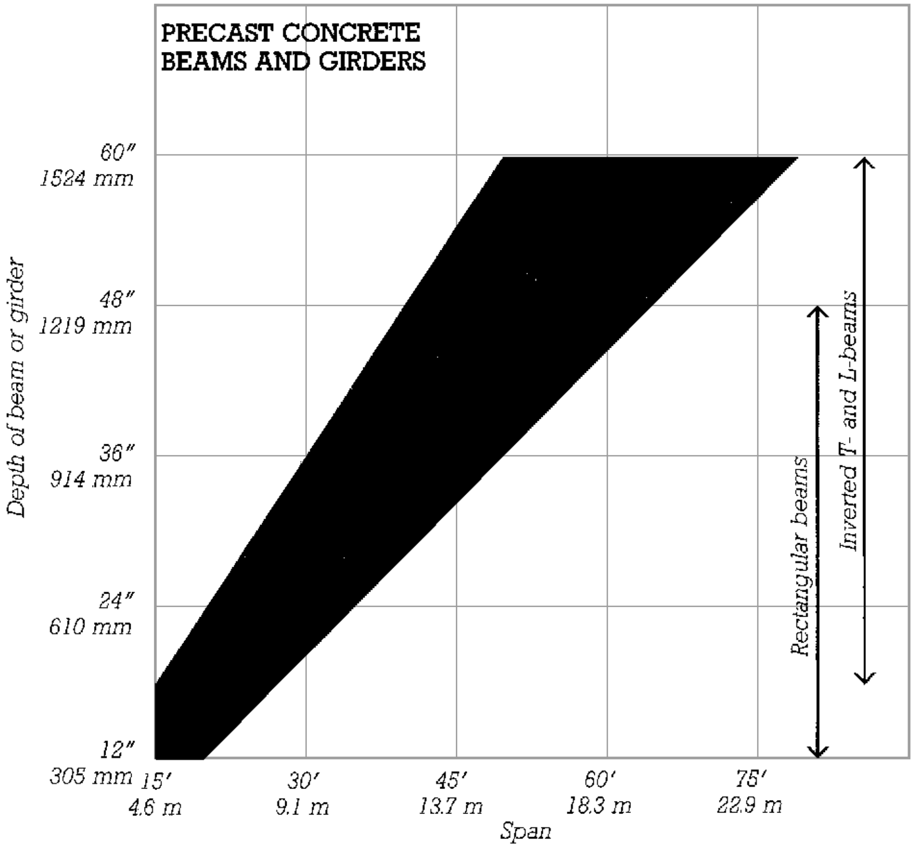
Precast concrete beams and girders can be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the placement of reinforcing. The following guidelines may be used for preliminary design:

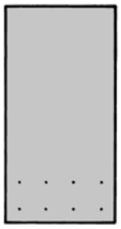
A prestressed concrete beam that is not smaller than 9.5 in. (241 mm) in width has a fire-resistance rating of 3 hours. For a 2-hour rating the minimum width is 7 in. (178 mm), and for 1 hour it is 4 in. (102 mm).



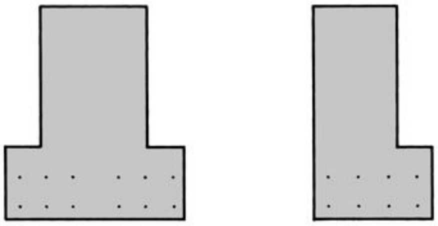
**INVERTED T-BEAM WITH DAPPED TEES**

# PRECAST CONCRETE BEAMS AND GIRDERS





**RECTANGULAR BEAM**



**INVERTED T- AND L-BEAMS**

This chart is for precast concrete beams and girders. For light loads or close beam spacings, read toward the right in the indicated area. For heavy loads and large beam spacings, or for girders, read toward the left.

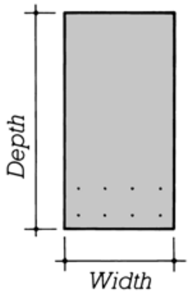
## COMMON SIZES OF PRECAST CONCRETE BEAMS AND GIRDERS

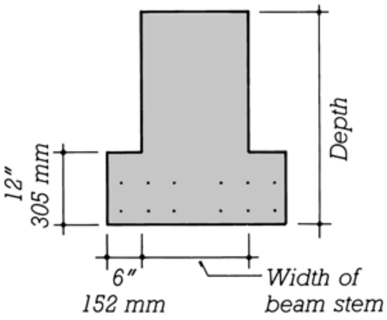
Rectangular beams commonly range in depth from 18 to 48 in. (450 to 1200 mm). Widths range from 12 to 36 in. (300 to 900 mm).

Inverted T- and L-beams commonly range in depth from 18 to 60 in. (450 to 1500 mm), although sections deeper than 48 in. (1200 mm) may be subject to shipping or handling restrictions. Widths of the beam stem (not including the ledges) range from 12 to 30 in. (300 to 750 mm).

Standard dimensions for beam ledges are 6 in. (150 mm) wide and 12 in. (300 mm) deep.

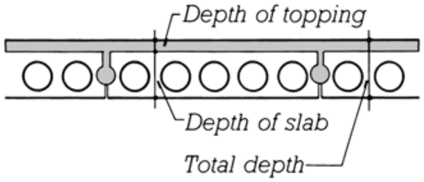
Beam sizes typically vary in increments of 2 or 4 in. (50 or 100 mm). Availability of sizes varies with suppliers.





# PRECAST CONCRETE SLABS

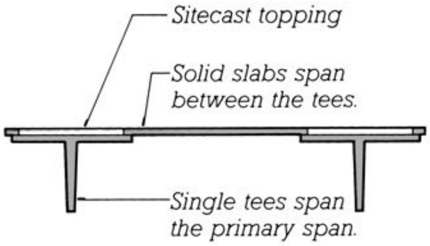
Precast prestressed concrete solid and hollow core slabs are commonly used in hotels, multifamily dwellings, commercial structures, hospitals, schools, and parking structures. Lighter weight slab systems also find use in residential home construction.



**HOLLOW CORE SLABS WITH SITECAST TOPPING**

## CONCRETE TOPPING ON PRECAST SLABS

Sitecast concrete topping is often applied over precast concrete slabs to increase the structural capacity of the slab, increase the fire resistance of the floor system, allow the integration of electrical and communications services into the floor, or provide a more level and smoother floor surface in preparation for subsequent finishes. In buildings such as hotels, housing, and some parking structures, where these requirements may not exist, the use of untopped slabs may be an acceptable and economical system choice.

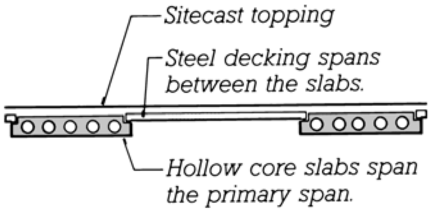


**SPREAD TEE SYSTEM WITH SOLID SLABS**

## SPECIAL SYSTEMS

Both solid and hollow core slabs may be combined with other spanning elements to create several types of hybrid floor structures that are referred to as *spread systems*. These systems can provide increased economy and may allow greater flexibility in the choice of building module.

- Either slab type may be used as a secondary element spanning transversely between longer spanning single tees, double tees, or channels.
- Hollow core slabs can be spread from 2 to 3 ft (0.6 to 0.9 m), with corrugated steel decking spanning between the slabs. This system is usually topped. Where many floor penetrations are expected, this is an attractive system due to the relative ease of creating openings through the steel decking.



**HOLLOW CORE SLAB SPREAD SYSTEM**

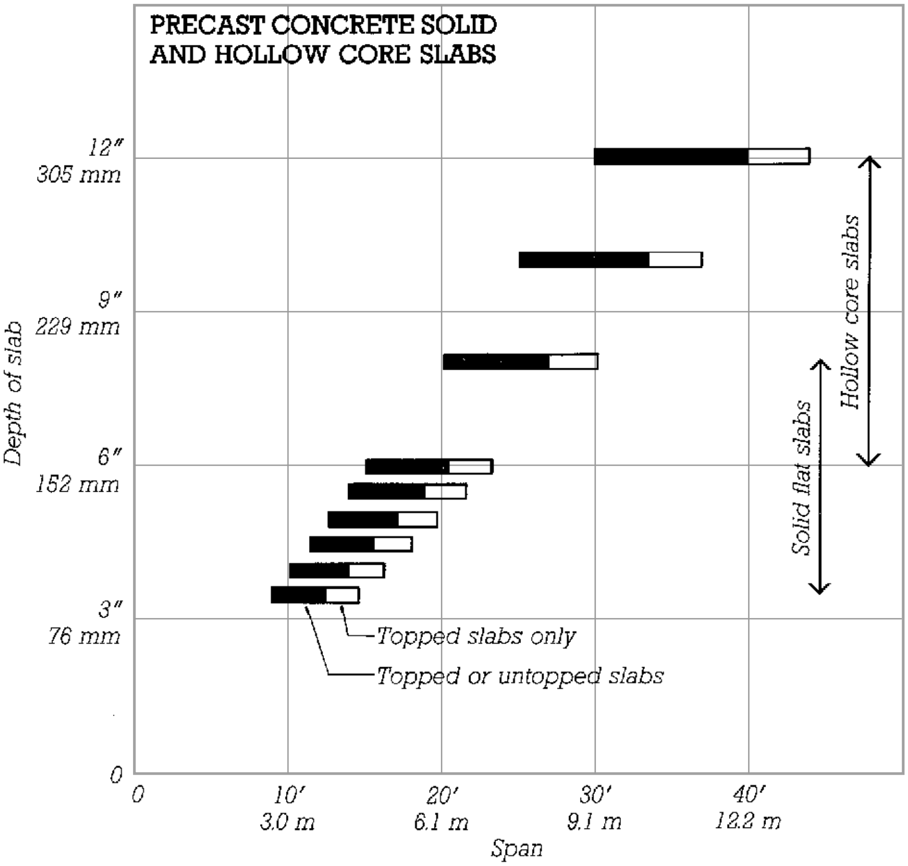
## FIRE-RESISTANCE RATINGS FOR SOLID FLAT SLABS AND HOLLOW CORE SLABS

Precast concrete slabs can be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete and the placement of reinforcing. Use the following guidelines for preliminary design:

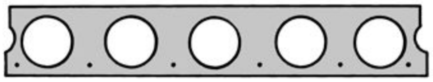
Solid slab floors must be at least 5.5 in. (140 mm) thick to have a fire resistance rating of 3 hours. For a 2-hour rating, the required thickness is 4.5 in. (115 mm). A 1½-hour rating requires a minimum thickness of 4 in. (100 mm), and a 1-hour rating requires a thickness of 3.5 in. (90 mm). These thicknesses include the depth of any topping.

Hollow core slabs at least 8 in. (200 mm) deep achieve a fire-resistance rating of 2 hours without a concrete topping. With the addition of a 2-in. (50-mm) topping, the rating rises to 3 hours.

# PRECAST CONCRETE SLABS



**SOLID SLAB**



**HOLLOW CORE SLAB**

This chart is for precast concrete solid flat slabs and hollow core slabs. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

■ The open areas indicated on the chart are for slabs with an added sitecast concrete topping only. The solid areas are for either topped or untopped slabs. The depths indicated on the chart are for the slabs alone, without any additional topping. Where a topping is used, add 2 in. (50 mm) to the indicated depths for preliminary design. See the facing page for further information on the use of concrete toppings.

## COMMON SIZES OF SOLID AND HOLLOW CORE SLABS

Solid flat slabs come in depths of 3½ to 8 in. (90 to 200 mm). For depths of 6 in. (150 mm) and above, however, hollow core slabs are usually more economical. Typical widths are 8 to 12 ft (2.4 to 3.7 m).

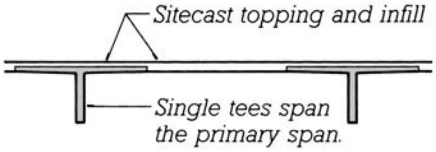
Hollow core slabs come in depths of 6 to 12 in. (150 to 300 mm). Typical widths are 2 ft, 3 ft 4 in., 4 ft, and 8 ft (0.6, 1.0, 1.2, and 2.4 m). Availability of sizes varies with suppliers.

# PRECAST CONCRETE SINGLE AND DOUBLE TEES

Precast prestressed single and double tees can span farther than precast slabs and are commonly used in building types such as commercial structures, schools, and parking garages.

## SPREAD TEE SYSTEMS

Single and double tees may be combined with other spanning elements to create hybrid framing systems referred to as *spread systems*. In these systems, the tees are erected with spaces between them. These gaps are then bridged with precast solid or hollow core slabs, or with sitecast concrete that is poured as part of the topping. These systems can increase the economy of long-span structures and may allow greater flexibility in the choice of building module.



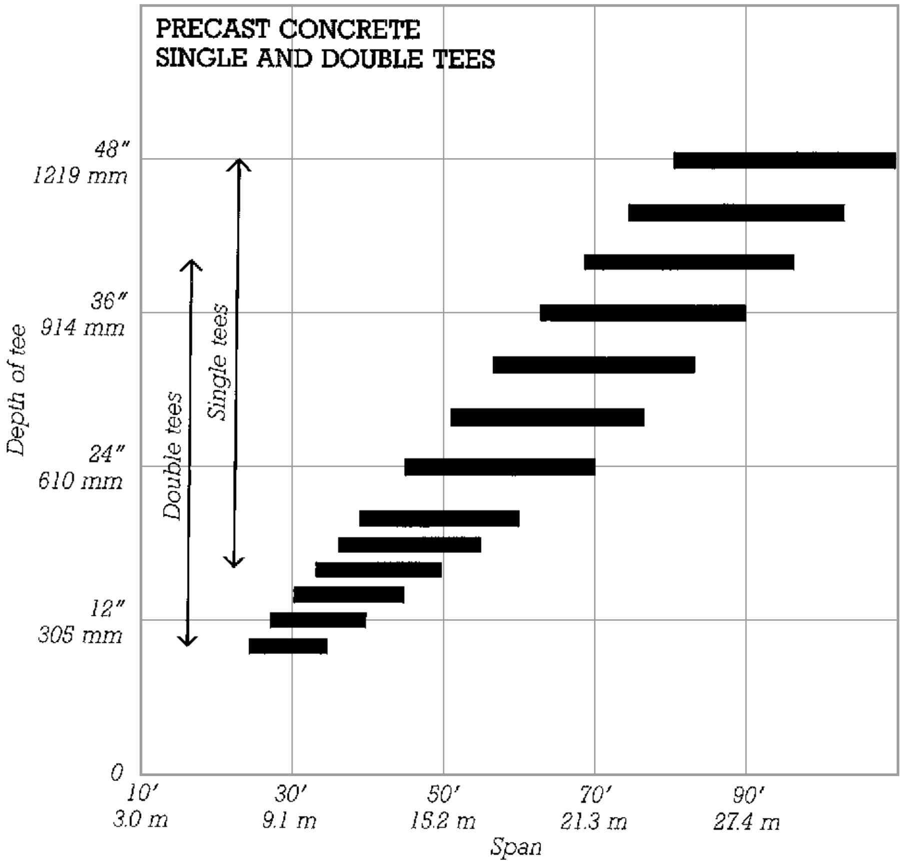
**SPREAD TEE SYSTEM WITH SITECAST CONCRETE TOPPING AND INFILL**

## FIRE-RESISTANCE RATINGS FOR SINGLE AND DOUBLE TEES

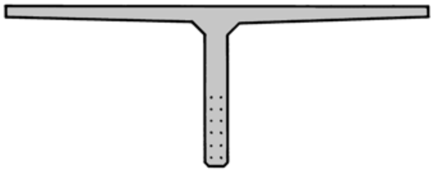
Precast concrete single and double tees may be used in both Combustible and Noncombustible Construction. Their fire resistance varies with the composition of the concrete in the slabs and topping and with the placement of reinforcing. Use the following guidelines for the preliminary design:

For a fire-resistance rating of 3 hours, single and double tees require applied fire-protection materials or an appropriately fire-resistive ceiling. For ratings of 2 hours and less, protection may be achieved by regulating the thickness of the concrete topping: 3.5 in. (90 mm) for 2 hours, 3.0 in. (75 mm) for 1½ hours, and 2.0 in. (50 mm) for 1 hour.

# PRECAST CONCRETE SINGLE AND DOUBLE TEES



**DOUBLE TEE**



**SINGLE TEE**

This chart is for precast concrete single and double tees. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

■ Because they do not require temporary support against tipping, double tees are faster and more economical to erect than single tees. Their use is preferred wherever possible.

■ Double tees are most commonly used with a concrete topping. For preliminary purposes, add 2 in. (50 mm) to the depths indicated on the chart. Roof slabs and deep single tees may not need to be topped.

## COMMON SIZES OF PRECAST SINGLE AND DOUBLE TEES

Double tees come in widths of 4, 8, 10, and 12 ft (1.2, 2.4, 3.0, and 3.7 m). Common depths are 10 to 40 in. (250 to 1000 mm). Single tees come in widths of 6, 8, 10, and 12 ft (1.8, 2.4, 3.0, and 3.7 m). Common depths are 16 to 48 in. (400 to 1200 mm). Tees longer than 60 to 80 ft (18 to 24 m) may be less economical because of increased transportation and handling costs. Availability of sizes varies with suppliers.

## SECTION

## 3

# DESIGNING WITH DAYLIGHT

# 1

# DESIGN CRITERIA FOR DAYLIGHTING SYSTEMS

***This chapter will help you evaluate the suitability of daylight illumination to your project and, if you choose to proceed with daylighting design, to select appropriate daylighting strategies.***

# DESIGN WITH DAYLIGHT

Daylighting is the use of natural light to illuminate the interior of a building. Daylight can provide high-quality, color-balanced lighting. It can reduce a building's energy consumption, contribute to the conservation of natural resources and the protection of the environment, improve the aesthetic quality of the workplace, provide a psychological connection to nature and the outdoors, and increase business productivity. There are many factors that influence the potential for daylighting design on a project. Location, climate, building form, program, and the perceived value of daylighting by the building's owners and its occupants can all play a role. When buildings are designed for daylight illumination, the architectural impact is significant. Massing, orientation, structural configuration, layout of interior elements and spaces, and choice of materials are all influenced by daylighting considerations. For these reasons, daylighting should be addressed at the earliest stages of design, when the opportunities for successfully incorporating effective strategies into a project are greatest. The information in the following pages will help you evaluate the potential of daylighting for your project, and, if you choose to pursue this option, provide preliminary design guidelines for developing a building that effectively utilizes natural daylight for illumination.

A quality luminous environment requires adequate levels of illumination; it requires light that is well distributed to prevent excessive contrast, brightness, and glare; and it requires light that is reliably available. Sources of daylight include both the sun and the surrounding, clear or clouded, luminous sky. Direct sunlight is too intense to be allowed to fall directly on tasks or within the visual field. It must be diffused, reflected, or moderated in some way. Furthermore, direct sunlight is not necessarily the most reliable source of daylight. The sun's position in the sky changes constantly, causing the quality of its light to vary with orientation, time of day, and season. At any time, the sun may be obscured by cloud cover, geographic features, or nearby man-made structures. For these reasons, the simplest way to incorporate daylighting into most projects is to rely on indirect sky light as the primary source of illumination and, where sunlight is present, to ensure that it does not directly intrude into the task area. This is the daylighting approach emphasized in the following pages.

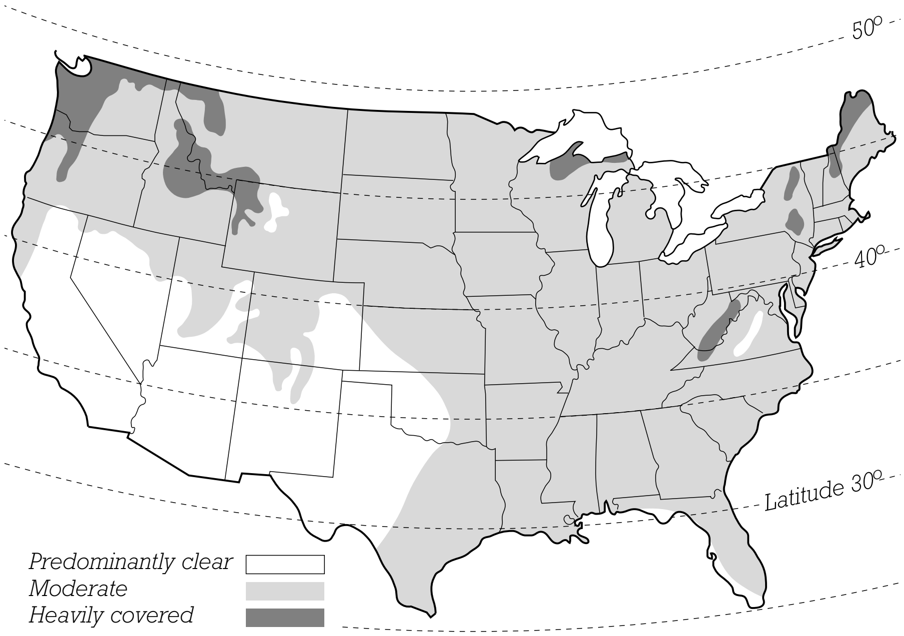
Designs utilizing direct sunlight as the primary source of illumination are also feasible, particularly in areas with prevailing clear skies. The information provided here is relevant to such projects as well. However, the behavior of such systems is more complex, and their design will require more sophisticated analysis and modeling techniques than provided here.

# SKY COVER

The map on this page indicates average clear and covered (cloudy) sky conditions within the continental United States. Conditions are characterized as *predominantly clear*, *moderate*, or *heavily covered*, corresponding to an average annual sky cover of less than 50%, from 50% to 70%, or greater than 70%, respectively. Only in areas indicated as predominantly clear—mainly the Southwest and parts of Florida—are clear skies prevalent on average more than half of all daylight hours. In the remaining areas—most of the continental United States—covered or partially covered sky conditions predominate more than half of the time. Though not shown on this map, the heavily populated regions of Canada are within moderately or heavily covered areas as well.

In predominantly clear areas, direct sun is most prevalent and levels of available daylight are consistently highest. Consequently, in using the sizing charts shown toward the end of this chapter for projects falling within predominantly clear areas, you should read low in the recommended lighting level ranges because of the higher available light levels. In areas characterized as having moderate sky cover, sky conditions are more variable. In using the sizing charts for projects falling within moderate sky cover areas, you should read near the middle of the recommended lighting level ranges. In heavily covered areas, cloudy skies predominate and average daylight availability is lowest. When using the sizing charts for these projects, you should read near the top of the recommended lighting level ranges. Because local sky conditions can vary from regional averages, the information presented here should be supplemented with local data wherever possible.

Regardless of sky cover conditions, control of direct sunlight is always an important consideration. To prevent unacceptable levels of glare and contrast, sunlight should always be prevented from falling directly within the visual field of task areas.



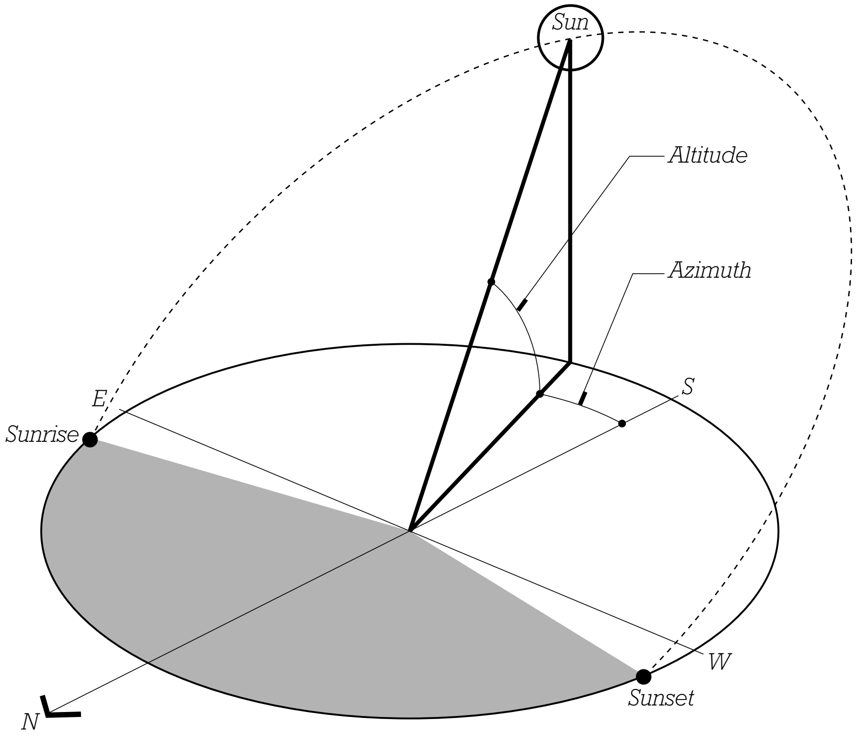
**SKY COVER CONDITIONS**

# THE PATH OF THE SUN

The sun moves over and around a building during the course of each day. Successful daylighting design requires that the building occupants receive acceptable levels of consistent, quality illumination throughout this cycle. The chart below provides information about the path of the sun for various latitudes and different times of the year, information that is important to understanding the impact of the sun on a building. To find the approximate latitude for a project located in the continental United States, use the latitude indications on the Sky Cover Conditions map on the previous page. For other locations, consult comparable sources of information. As an example, Savannah, Georgia, lies approximately at 32° North latitude. At the summer solstice, June 21, the sun rises at an azimuth of 115° (measured from the South axis), and at solar noon it reaches an altitude of 81° (measured from the horizon). The length of the day from sunrise to sunset is approximately 14 hours.

The path of the sun also varies over the course of the year, the magnitude of this variation increasing with greater distance from the equator. For example, at 24° North latitude, from summer solstice to winter solstice, the length of the day varies by 4 hours and the sun's rising or setting position moves on the horizon 47°. In comparison, at 52° North latitude, the length of the day varies by 8 hours, and the sun's rising or setting position moves 120°. In addition, at 24° North latitude, at the winter solstice, the sun rises to 42° above the horizon at noon. At 52° North latitude, it rises only 16° above the horizon at its highest point.

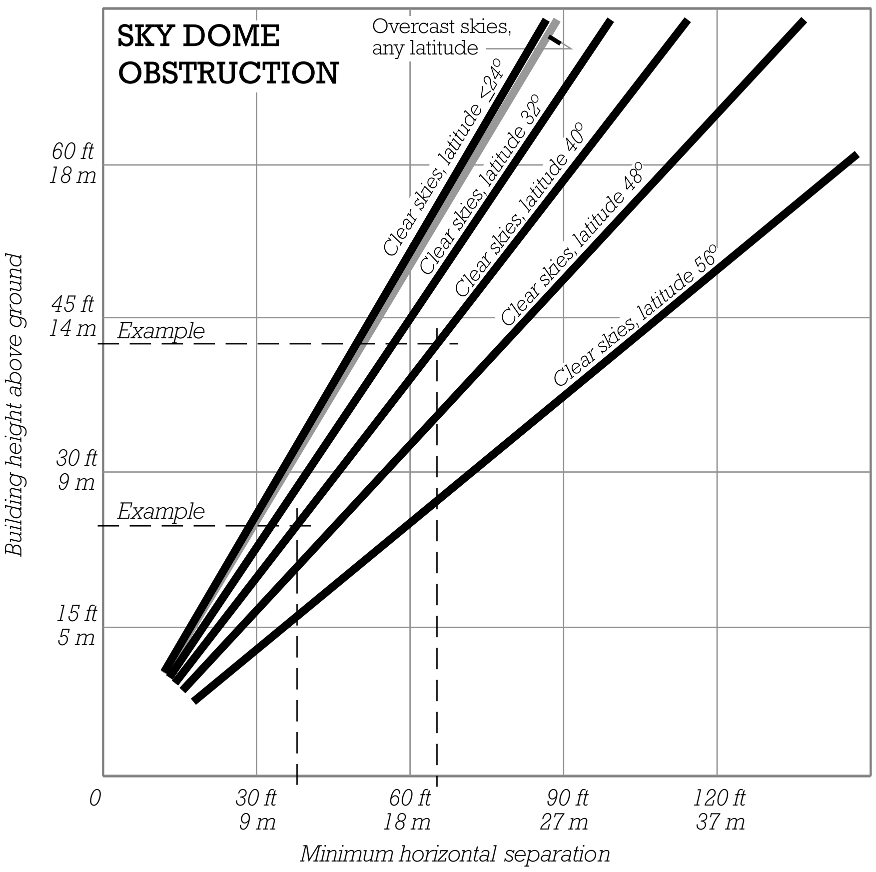
Use the information in this table to chart the approximate path of the sun around your building. As you continue on the following pages, this information will help you to determine a favorable building orientation and opening configuration in order to maximize daylight access and limit exposure to unwanted direct sunlight. In particular, pay special attention to times of the day and year when the sun is low in the sky. These times present the most difficult problems for sunlight control. Attention to building orientation, configuration of daylight openings, and the anticipated hours of building occupancy should all be considered relative to these low-angle sun conditions.

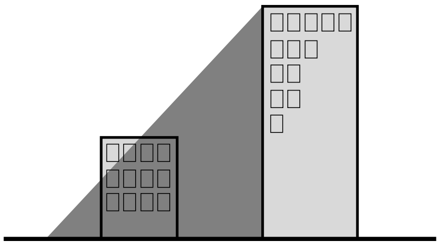


THE PATH OF THE SUN

| Latitude | Hours of Daylight (sunrise to sunset) | Altitude of Noon Sun | Azimuth of Rising or Setting Sun |
|---|---|---|---|
| 24° North | | | |
| Summer Solstice | 14 | 90° | 115° |
| Winter Solstice | 10 | 42° | 68° |
| 32° North | | | |
| Summer Solstice | 14 | 81° | 115° |
| Winter Solstice | 10 | 36° | 62° |
| 40° North | | | |
| Summer Solstice | 14 | 74° | 120° |
| Winter Solstice | 9 | 28° | 60° |
| 48° North | | | |
| Summer Solstice | 15 | 66° | 125° |
| Winter Solstice | 8 | 20° | 55° |
| 52° North | | | |
| Summer Solstice | 16 | 62° | 130° |
| Winter Solstice | 8 | 16° | 50° |

# SKY DOME OBSTRUCTION





Daylighting design requires a building to have line-of-sight access to sufficient sky area for adequate daylight exposure. The chart above can be used in two ways: first, to determine the extent to which surrounding structures may obstruct your building's access to daylight, and second, to determine the extent to which your building obstructs surrounding structures' access to daylight.

For example, assume a project location at 40° North latitude, with clear sky conditions, a neighboring building 24 ft (7 m) tall, and a planned height of 42 ft (13 m) for your building. To ensure that your building has full access to daylight, read the chart using the adjacent building's height of 24 ft (7 m) to determine that there should be at least 37 ft (11 m) between the two structures. To ensure that the adjacent building's daylight is not obstructed by your project, read the chart using your building's height of 42 ft (13 m) to determine that there should be at least 65 ft (20 m) between the two structures. To protect access to daylight for both buildings, use the larger of the two answers, in this case, 65 ft (20 m).

This chart is for determining daylight obstruction between buildings.

■ To ensure full access to daylight for your building, read the chart using the height of adjacent buildings or structures. Locate your building so that it is at least as far away from each of these structures as indicated on the chart.

■ To ensure that your building does not obstruct access to daylight for adjacent structures, read the chart using the height of your building and locate your building at least as far away from the adjacent structures as indicated.

■ For buildings located in predominantly covered sky areas at any latitude, read the chart along the sloped line for overcast skies. For buildings located in predominantly clear sky areas, read the chart along the sloped line for the latitude of the project or interpolate between lines for other latitudes. For buildings located in moderate sky cover areas, read along the line for overcast skies to find the optimum building separation under worst-case conditions, or read along the appropriate line for clear skies to determine building separation under more favorable clear sky conditions. (For more information on determining sky cover conditions and the latitude of a project, see page 141.)

# BUILDING SITING AND SHAPE

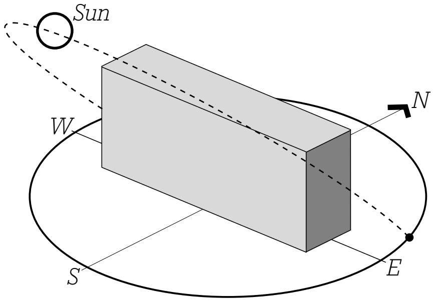
Daylighting design is intimately related to building form. This section provides guidelines for the siting, massing, and internal configuration of a building to provide the greatest opportunities for successful daylighting.

## BUILDING SIZE

Strategies for daylighting differ with building size. For small buildings, the ratio of exterior skin area to enclosed volume is relatively large. This means that for residences and small-scale nonresidential buildings, generally the designer has ample opportunities to locate occupied areas in close proximity to daylight sources such as windows and rooftop openings. In small buildings, the main challenge for the designer is to control the quality of the daylight, distributing it effectively and avoiding excessive contrast or brightness. On the other hand, in large buildings, the ratio of exterior envelope area to enclosed volume may be much less, and providing adequate levels of daylight to interior areas becomes a design challenge with greater formal implications. In large buildings, both building shape and interior configuration become critical to a successful daylighting scheme.

## ORIENTATION

Daylight openings should be oriented to allow the control of direct sunlight while providing access to sources of daylight that are consistent in quality and provide high levels of illumination. In the Northern Hemisphere, these conditions are best met in a south orientation, where for the largest part of the day, the sun remains high in the sky and the surrounding sky provides high levels of manageable daylight. A northern exposure is also favorable, providing consistent daylight, though at illumination levels lower than those from a southern exposure. The most difficult orientations for daylight openings are toward those portions of the sky in which the sun is low in its daily path, generally toward the east and west, though precise orientation varies with location and time of year. These exposures should be avoided or, if used, studied carefully, as the quality of the daylight is highly variable and the control of direct sunlight is problematic. Thus, buildings elongated in the east–west direction, and plan configurations that otherwise maximize exposure to the north and south sky while shielding exposure to the east and west, will generally provide the most favorable daylighting opportunities. In some cases, strategically located adjacent structures may also play a role in shielding a building from unfavorable exposure to the sun when it is low in the sky.

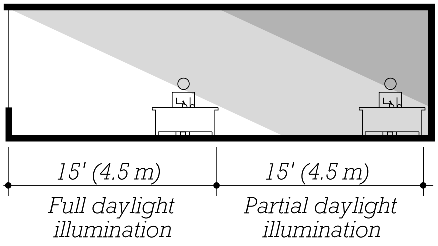


**BUILDING ORIENTATION**

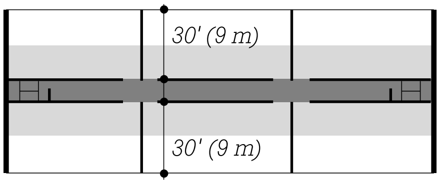
## BUILDING SHAPE

In multistory buildings, daylight is mostly provided through windows in exterior walls. Daylighting such as this is termed *sidelighting*, and its effectiveness is limited by the depth to which it can penetrate horizontally into the building's interior. For example, in a typical office building, daylighting can provide full illumination to task areas no farther than 12 to 15 ft (3.5 to 4.5 m) from exterior wall openings and can provide partial illumination to areas no farther than 24 to 30 ft (7.5 to 9 m) from the exterior. Thus, to maximize effective daylighting in a commercial office building, work areas should be located, to the greatest extent possible, no more than 30 ft (9 m) from exterior walls with daylight access. Consider, for example, a double-loaded corridor plan. Total building depth in the north–south direction should not exceed approximately 70 ft (21 m), allowing 30 ft (9 m) for work areas on either side of a 10-ft (3-m)-wide central corridor. In general, narrow or elongated plans, L- or U-shaped plans, and courtyard or atrium buildings provide greater access to daylight than more compact arrangements.

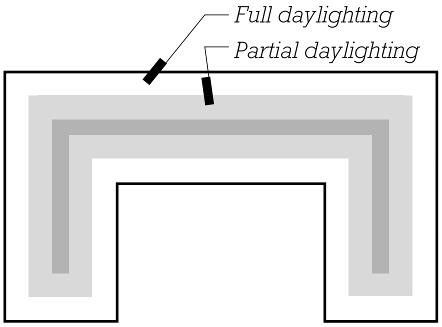
Where occupied areas occur directly below roofs, daylighting may also be provided through overhead skylights or other types of roof openings, devices collectively referred to as *toplighting*. Large single-story buildings, such as factories or warehouses, are well suited to toplighting configurations. Opportunities for toplighting can be increased with building sections that step or are otherwise configured to create increased roof area. Considering sidelighting and toplighting together, daylighting design generally benefits from elongated or articulated building massing that increases the building perimeter and thereby increases opportunities for daylight access to the interior.



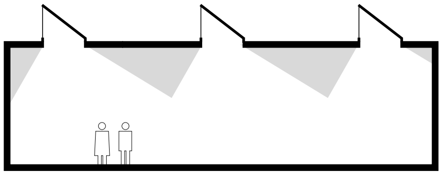
SIDELIGHTING



DOUBLE-LOADED CORRIDOR



ELONGATED BUILDING PLANS



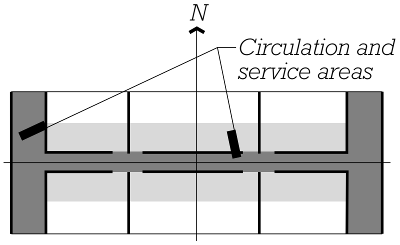
TOPLIGHTING

## BUILDING DESIGN DEVELOPMENT

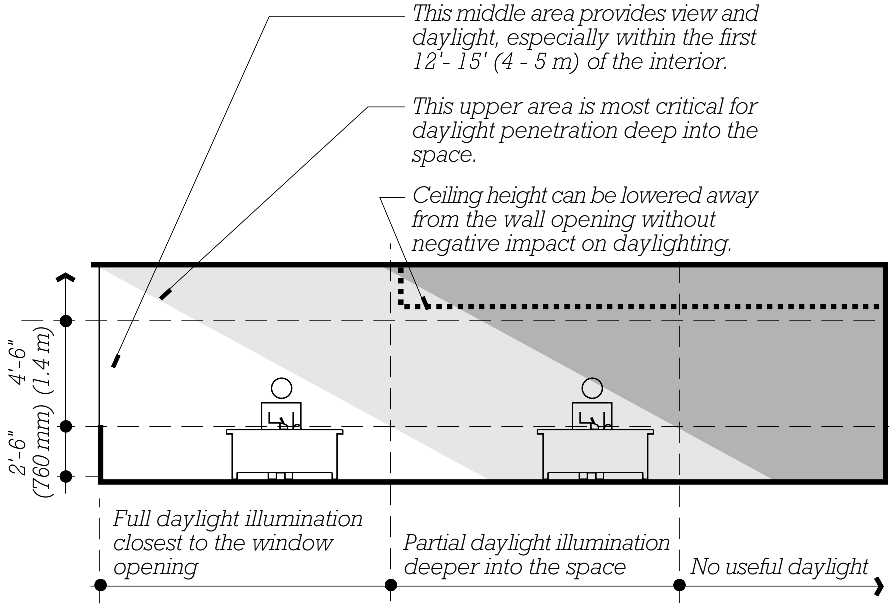
As a design progresses and the building configuration continues to develop, the impact of daylighting should be investigated in more detail and with more attention to local conditions. For example, a building not oriented on the cardinal points of the compass may interact with early morning and late afternoon sun in ways that require more detailed investigation. Local topography and weather patterns may affect access to daylight at various times of the day or year. Adjacent structures may reflect light or obscure the sky in ways that positively or negatively affect a project. Patterns of use within a building may also favor certain orientations or times of day. For example, an elementary school building in which classrooms are unoccupied after 3 P.M. may be more tolerant of a western exposure than a commercial office space habitually occupied until later in the day. As the project design develops, more detailed analysis, daylighting modeling, and the advice of daylighting experts should all be used.

# BUILDING INTERIOR CONFIGURATION

Not all activities within a building necessarily benefit equally from daylighting, and an analysis of the lighting needs of the various components of the program can help guide decisions regarding where each component may be located. For example, vertical circulation, bathrooms, and storage gain little if any benefit from daylighting and can be located in portions of the floor plate that daylight cannot reach. Or such functions can be grouped on the east and west ends of a building, acting as shields against these problematic exposures.



**SHIELDING EAST AND WEST EXPOSURES**



**DAYLIGHT ZONES AND THE WINDOW WALL** ***(Thanks to Joel Loveland, University of Washington Department of Architecture and Seattle Lighting Design Lab for the concept of this diagram.)***

A critical factor in daylighting design is the treatment of ceiling height, especially close to the exterior. Considering the section diagram on this page, the exterior wall can be divided into three distinct zones. The portion of the wall below 30 in. (760 mm), roughly the level of a typical work surface, makes no significant contribution to daylighting. Openings in the middle portion of the wall, up to approximately 7 ft (2.1 m), provide daylighting in areas closest to the opening and offer exterior views. To maximize the effectiveness of daylight illumination deeper in the space, the window opening must extend above 7 ft (2.1 m), necessitating a ceiling as high as possible and the avoidance of spandrel beams or other elements close to the perimeter that can obscure this portion of the wall opening. This criterion places significant constraints on the planning of structural and mechanical building systems, such as the location of deep beams or HVAC ductwork, and must be considered in the earliest stages of design if it is to be achieved. (For more detailed information about window opening height and daylight horizontal penetration, see pages 151–153.)

For a task area to benefit significantly from daylight illumination, a source of daylight, such as a window, skylight, or surface off which daylight is reflected, must be directly in the line of sight with that task area. Partitions, structural elements, mechanical and electrical system components, furnishings, and other elements that extend above the lower third of the space should be arranged to minimize their potential to obstruct daylight sources. See page 152 for more information about configuring interior elements for optimal daylighting.

## SMALL BUILDINGS

Small building energy consumption tends to be driven primarily by heating and cooling loads associated with thermal exchange through the building's exterior skin. Thus, in cold climates, energy consumption is dominated by the need to replace heat lost through the walls and roof during the cold months. In warmer regions, energy consumption may be driven by the removal of heat gained through the exterior envelope during the warm months. Daylighting design can contribute to the reduction of energy consumption in both of these circumstances.

In cold climates, south-facing sidelighting can provide daylight illumination as well as solar heat gain for energy savings. Where direct sun is admitted into the structure as a source of heat, internal shading, diffusing, or reflecting devices should be used to protect visual task areas from excessive brightness or contrast. To control heat gain during warmer months, external overhangs or other shading devices can be used to exclude direct sun from the interior during these periods. For more information on solar heating strategies for small and medium-sized buildings, see pages 222–224.

Daylight illumination can also contribute to reduced cooling loads in warm climates. Indirect light from the north sky or from well-shaded southern exposures is an excellent source of illumination with low heat content. Direct sunlight can be reflected off exterior surfaces before it is admitted into a structure, thereby leaving a significant portion of its heat content outside the building. And, as explained in more detail in the next section, even direct sunlight can be an energy-efficient source of illumination when it is properly controlled and efficiently distributed within the interior.

## LARGE BUILDINGS

In larger buildings, energy consumption is increasingly dominated by internally generated heat loads, rather than by heat exchange through the building skin. The removal of heat generated by occupants, lighting, and equipment is often the most significant factor in the overall energy performance of a large commercial building.

In conditions such as these, daylighting can contribute significantly to energy savings. Natural daylight illumination is free. Wherever daylighting can replace an electric light source, electric energy consumption is reduced directly. In addition, because well-designed daylight illumination generates less heat than common sources of artificial illumination, daylighting can lessen a building's internal heat load, further reducing energy consumption. The following chart tabulates the *efficacy* of daylight and several forms of electric lighting—that is, the amount of useful light in relation to the heat produced (measured in lumens per watt). The higher the efficacy, the more energy efficient is the light source. Note that daylighting compares favorably to common types of indoor electric lighting.

For daylight to achieve its potential for high efficacy, it must be well utilized within the building. Direct sunlight that causes excessive heat gain, or daylighting that in other ways creates an unsatisfactory visual environment, will not reduce the use of electric light or save energy. However, when well designed and implemented, natural daylighting offers significant opportunities for savings in large building energy consumption.

| **Light Source Efficacy, Measured in Lumens/Watt (Higher values indicate higher efficiency)** | |
|---|---|
| Natural daylighting | 90–150 lm/W |
| Incandescent lighting | 10–25 lm/W |
| Light-emitting diode lighting | 30–100 lm/W |
| Fluorescent lighting | 55–110 lm/W |
| Metal halide lighting | 65–115 lm/W |

# 2

# CONFIGURING AND SIZING DAYLIGHTING SYSTEMS

***This chapter will help you lay out the components of a daylighting system and estimate the size of daylight openings to provide the required levels of interior illumination for a project.***

# RECOMMENDED ILLUMINANCE LEVELS

Different tasks require different levels of illumination. The nature of a task, the need for accuracy and efficiency, and the visual acuity of the occupants are all contributing factors. For example, navigating the lobby of a commercial office building requires minimal attention to detail and is not a task with unusual demands for speed or accuracy. Consequently, relatively low ambient lighting levels are acceptable. On the other hand, an accountant, much of whose day is spent reading and transcribing densely formatted, low-contrast financial statements and ledgers, and whose efficiency and accuracy of work are critical, requires significantly higher levels of task illumination. Follow the steps below to determine recommended lighting levels for a project and to estimate the size and quantity of daylight sources for your building.

| | |
|---|---|
| **General Space Illumination** | |
| Category A — Public spaces, dark spaces | Nighttime corridors and lobbies, waiting rooms, bedrooms |
| Category B — Simple orientation | Dance halls, dining halls, transportation terminal concourses, residential living spaces |
| Category C — Occasional visual tasks | Daytime corridors and lobbies, reception areas, auditoriums, banks, worship spaces |
| **Task Illumination** | |
| Category D — Visual tasks of high contrast or large size | Conference rooms, office work with high-contrast tasks, factory simple assembly, residential kitchens |
| Category E — Visual tasks of medium contrast or small size | Drafting of high-contrast work, classrooms, offices, clerical tasks, factory work of low contrast or moderately difficult assembly |
| Category F — Visual tasks of low contrast or very small size | Drafting of low-contrast work, laboratories, factory work with difficult assembly |

**Step 1: Choose a Lighting Level Category**
From the chart on this page, make a preliminary choice of lighting level by selecting the category that most closely matches the activity that takes place in the given space.

**Step 2: Adjust Your Choice**
Each lighting level category represents a range of illumination levels suitable for the tasks described. On the charts on the following pages, each category is shown as a band representing the range of values. When reading from charts, you may read higher or lower in the appropriate band, depending on the following factors:

Higher light levels are recommended in areas with occupants primarily of age 55 years or older, in areas with predominantly dark, nonreflective surroundings or task backgrounds, and in areas where tasks are carried out that require an unusually high degree of speed and accuracy. If two or more of these factors apply, read *high* in the lighting level category bands in the following charts. Conversely, lower light levels are recommended in areas with occupants primarily under the age of 40, in areas with light-colored, highly reflective surroundings or task backgrounds, and in areas where tasks are carried out that do not demand unusual speed or accuracy. If two or more of these factors apply, read *low* in the lighting level category bands in the following charts.

## AMBIENT SPACE AND TASK ILLUMINATION

The table above lists recommended lighting levels for both general space illumination and task illumination, with task illumination requiring higher light levels because of the greater visual demands associated with these activities. For projects for which full reliance on daylighting is not achievable or desired, a strategy that may be considered is to provide ambient space illumination with daylighting and supplement this with electric lighting for task illumination. Thus, for example, where a typical office space may require Category E task illumination levels at the worker's desk, Category C illumination levels should be adequate for movement around these areas. In this case, daylighting design can be based on Category C illumination levels and task lighting at the desk can be provided from electric sources.

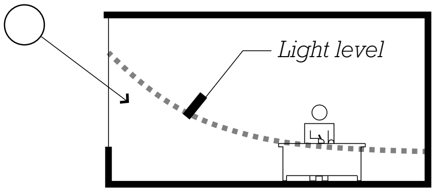
# SIDELIGHTING

With the exception of large single-story structures, sidelighting through windows and clerestories is the predominant means of providing daylight illumination in buildings.

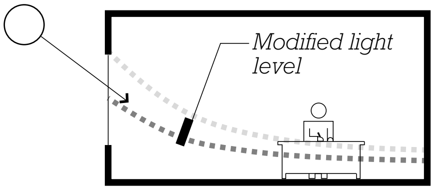
The intensity of sidelighting is highest near the opening and diminishes with increasing distance from the opening. The depth to which sidelighting can provide illumination within a building is largely dependent on the height of the opening. Under typical conditions, sidelighting can provide effective illumination for depths up to approximately 2½ times the height of the opening above the plane of the work surface. For example, in an office with 9-ft (2.7-m)-high windows and 30-in. (760-mm)-high desks, the top of the window is 6½ ft (2.0 m) above the work plane, and daylight should be able to provide full illumination up to a depth of approximately 16 ft (5 m) (6.5 ft × 2.5 = 16.25 ft). For more detailed information on the depth of sidelighting penetration for various illumination levels and opening heights, see page 153.

In designing with sidelighting, attention must be given to maximizing its reach deep into the structure, as well as minimizing excessive brightness close to the wall openings. A variety of techniques are possible. *Light shelves* create more evenly distributed illumination levels throughout a space. Though light shelves may reflect some light deeper into the interior, their primary benefit comes from reducing brightness levels close to the window. By reducing the highest illumination levels, more uniform lighting is achieved overall, giving the impression of an improved lighting environment. Light shelves can also prevent direct sunlight from falling directly within the work area.

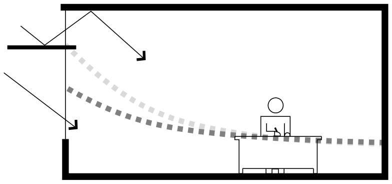
*Exterior overhangs* may be solid or louvered. Extending a solid overhang beyond the building wall is essentially the same as increasing the depth of the room, and illumination is reduced comparably. If light levels are adequate, this can be an effective way to block direct sun as well as reduce excessive brightness close to the window. Louvered overhangs, if designed with attention to prevailing sun angles, can block direct sunlight selectively while admitting indirect light.



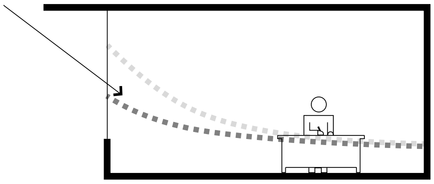
**SIDELIGHTING**



**REDUCED WINDOW HEAD HEIGHT**



**LIGHT SHELF**

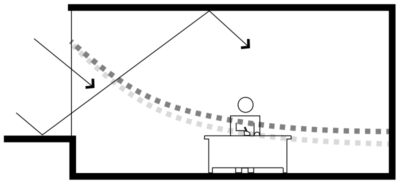


**EXTERIOR OVERHANG**

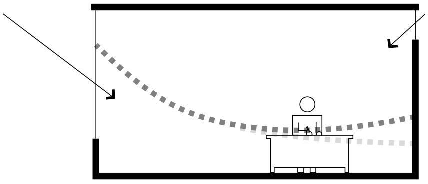
*Reflective sills* can increase the depth to which light penetrates within the space. However, care must be taken to avoid creating excessive glare for occupants close to the opening.

*Secondary sources* of daylight that are located at some distance from a primary wall opening, such as rear windows or skylights, can be used to increase light levels deep within a space, thereby creating more uniform lighting, as well as reducing strong shadowing and contrast.

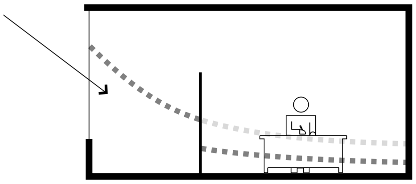
*Obstructions* to daylight within the space should be avoided. Wherever possible, elements that can block daylight, particularly those high up in the space, should be located as far from wall openings as possible. Where a plan includes both open plan areas and enclosed space, the open plan areas should be placed closest to the wall openings and the enclosed spaces should be located so as to minimize the obstruction of daylight. Where enclosed spaces must be located close to wall openings, consider transparent or translucent enclosing materials to allow daylight to penetrate beyond these areas. Opaque elements, such as partitions or ceiling beams, can assist in daylight distribution when oriented perpendicular to wall openings. Particularly when such elements are light-colored and located close to such openings, they can both reflect daylight more deeply into the space and reduce contrast levels close to the opening.



**REFLECTIVE SILL**



**SECONDARY DAYLIGHT SOURCE**



**DAYLIGHT OBSTRUCTIONS**

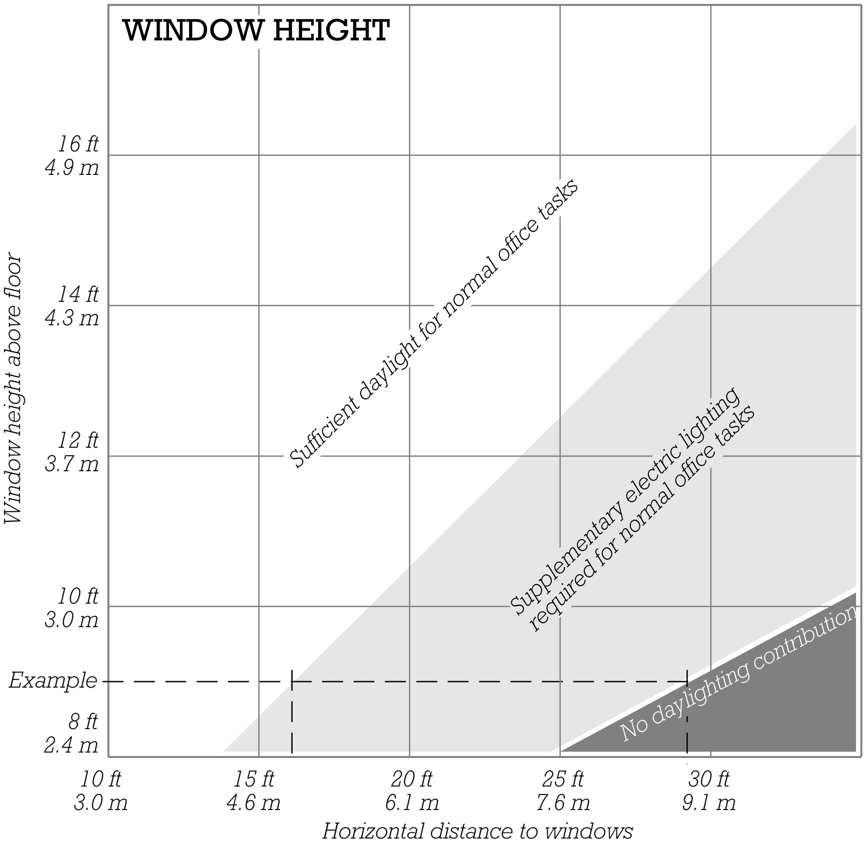
## SIZING SIDELIGHTING

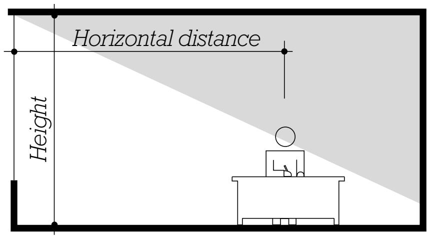
Use the charts on the opposite page to estimate the required size of wall openings for natural daylighting. Both charts assume that window bottoms are no higher than 30 in. (760 mm) above the floor, window glazing is clear, and walls and ceilings are white or light-colored. If these conditions are not met, daylighting effectiveness will be reduced.

For example, reading the top chart, a window extending 9 ft (2.7 m) above the floor will provide full daylighting for normal office tasks up to a horizontal distance of approximately 16 ft (4.9 m) from the window. Daylighting supplemented with electric lighting can be provided up to 29 ft (8.8 m) away.

As a second example, reading the bottom chart, a 6000-sq-ft (560-$m^2$) business office area is to be illuminated with daylight from adjacent windows. Using the table on page 150, we select Category E, visual tasks of medium contrast and size, as the appropriate lighting level. Reading the chart, we determine that 6000 sq ft (560 $m^2$) of floor area requires between 1000 and 2000 sq ft (93 and 186 $m^2$) of window area for full daylighting. Or, if electric task lighting is to be provided, general area illumination meeting Category C criteria can be provided with windows 200 to 400 sq ft (19 to 37 $m^2$) in area. (This scenario is not illustrated on the chart.)

# SIDELIGHTING



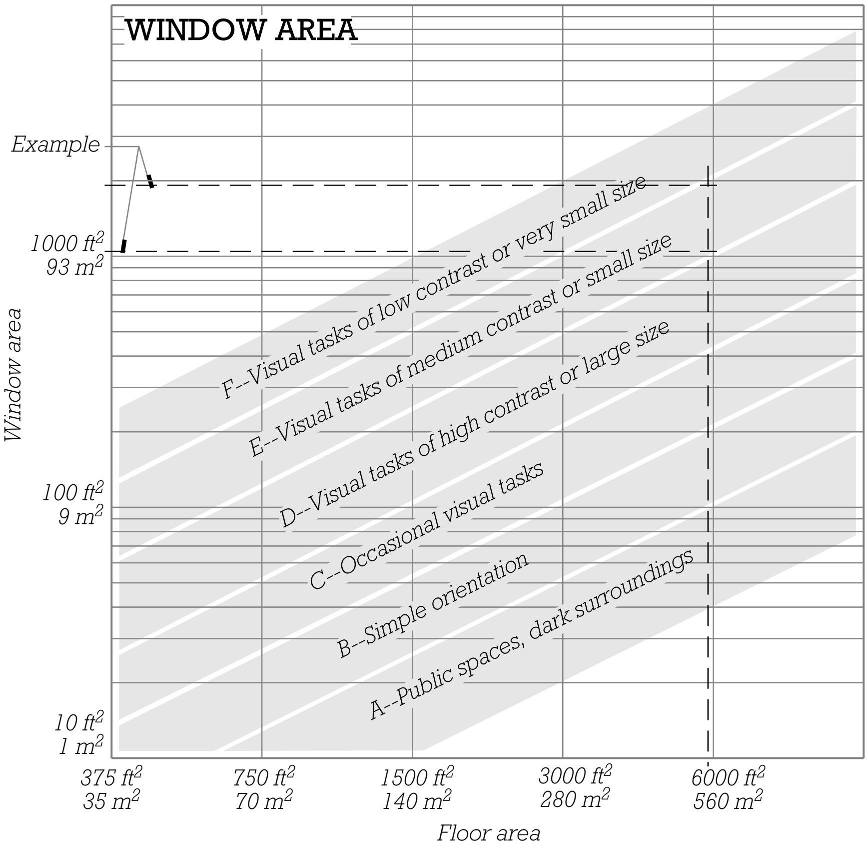


Use the top chart to determine the minimum wall opening height for adequate horizontal daylight penetration for normal office tasks.

■ To ensure even light distribution throughout a space, window openings should be at least half as wide as the length of the wall in which they are located. For more detailed help in estimating the required window area, see the chart below.

Use the bottom chart to determine the total wall opening area necessary for full daylighting of various tasks occupying a given floor area. To determine the most appropriate illumination category for the space under consideration, see page 150. For floor areas larger than those tabulated on the chart, read the chart using a smaller area and then multiply the result proportionally.

■ For buildings in predominantly clear sky areas, read low in the ranges indicated on the chart. For buildings in heavily covered sky areas, read high in the indicated ranges. See page 141 to determine the sky cover conditions for your project's location.



# TOPLIGHTING

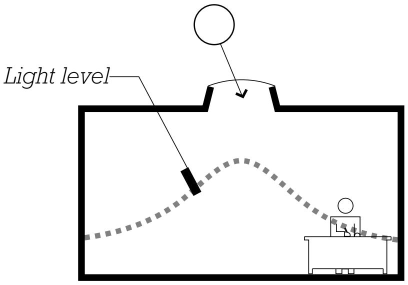
Toplighting is most effectively employed in large single-story structures. It may also find appropriate use in the topmost floors of multistory buildings.

Toplighting can be provided either by *skylights*, with horizontal or low-sloped glazing, or by *roof monitors*, with vertical or steeply sloped glazing. Because of variation in the brightness of the sky from horizon to directly overhead, illumination levels from skylights are roughly three times greater than those associated with sidelit windows of the same opening area. Illumination is highest directly below a skylight opening and diminishes with increasing horizontal distance. With roof monitors, which admit daylight from the side, highest illumination levels tend to be offset to the side opposite the monitor glazing. The intensity of illumination from roof monitors varies with their orientation. In the Northern Hemisphere, south-facing monitors provide illumination levels approximately equal to those of skylights of the same glazing area. Monitors facing other directions provide approximately one-half the illumination of a skylight of the same area.

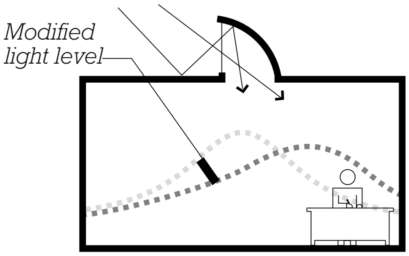
*Spaced toplighting* with multiple sources can minimize extremes in illumination levels. Sources of toplighting should be spaced no more than one to two times the height of the openings above the floor in order to provide acceptably uniform levels of illumination within the space.

In predominantly overcast areas, toplighting with clear glazing and no other means of sunlight control may be acceptable. In most areas, toplighting should be oriented away from the sun, or control devices should be used to prevent sunlight from passing unimpeded to the task area. *Interior reflectors*, exterior louvers, translucent light-diffusing materials, and deep openings with reflective sides can all be effective in this regard. When these devices are placed on the interior, they may also be helpful in distributing daylight farther from the opening and creating more even illumination within the space. Devices located exterior to the opening can exclude solar heat from the interior and may be helpful in areas where high heat gain is particularly a concern.

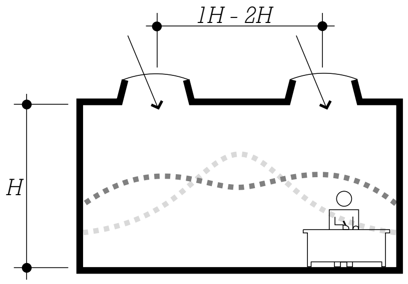
*Combined sidelighting and toplighting* can be used to distribute daylighting deeper into the interior than is possible with sidelighting alone. To avoid excessive variation in illumination levels, spacing of daylight sources should not exceed the recommendations in the adjacent diagram.



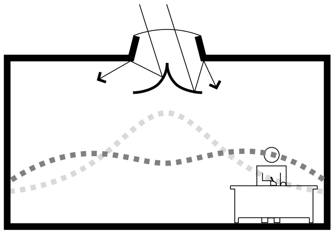
**SKYLIGHT**



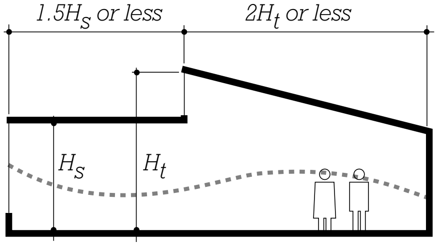
**ROOF MONITOR**



**SPACED TOPLIGHTING**



**INTERIOR REFLECTORS**



**COMBINED SIDELIGHTING AND TOPLIGHTING**

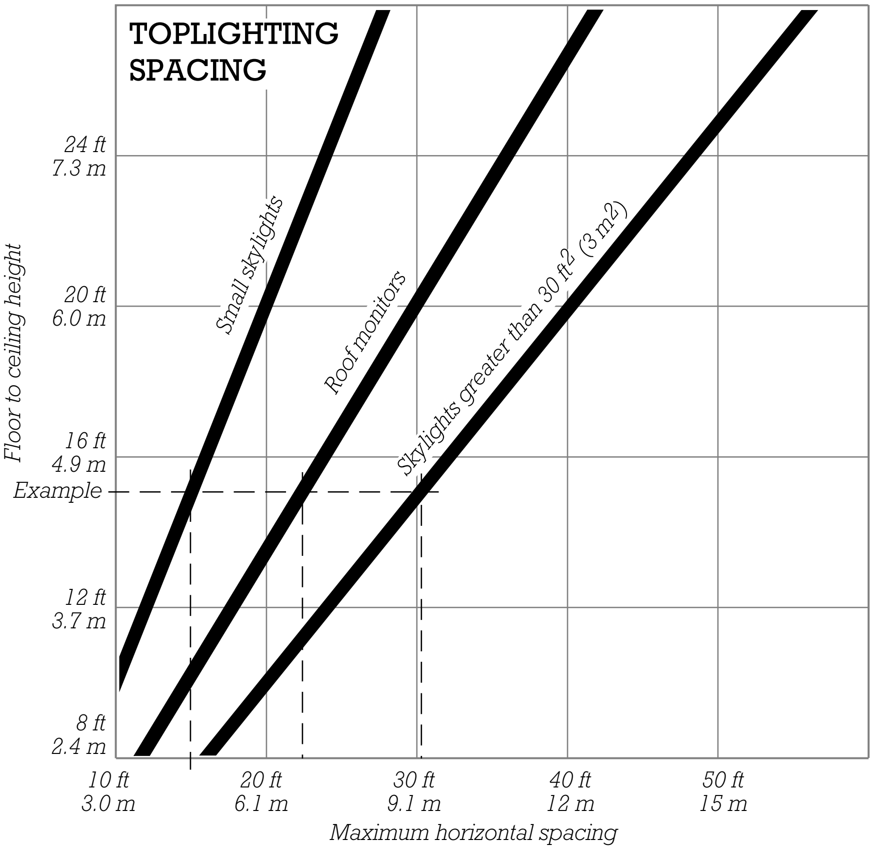
## SIZING TOPLIGHTING

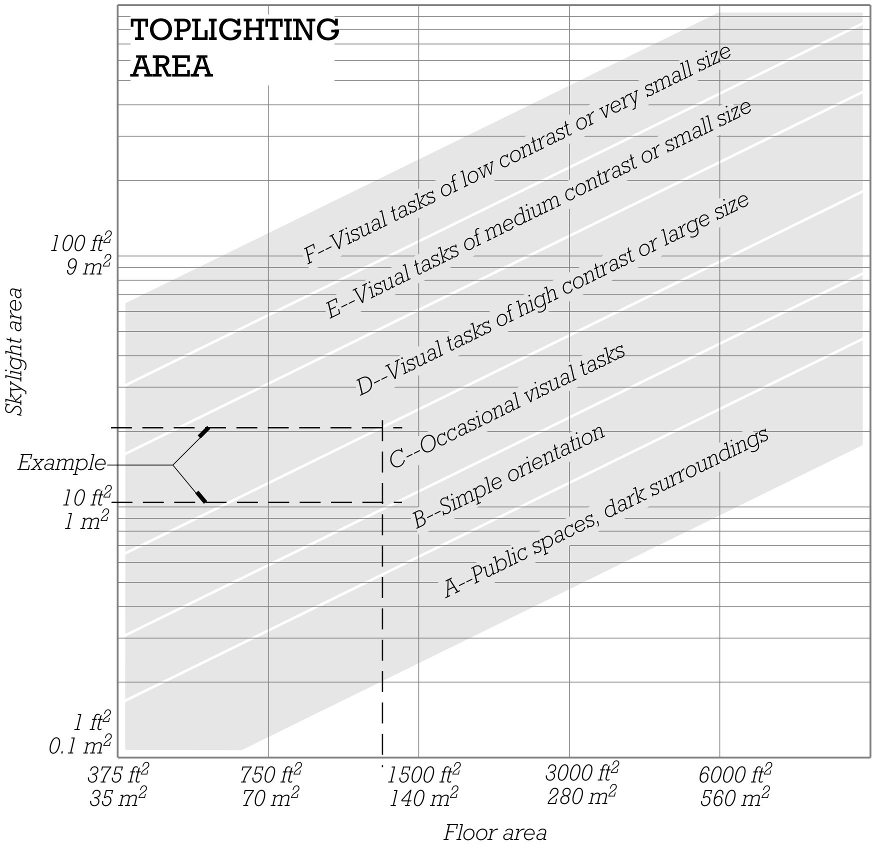
Use the charts on the facing page to estimate the required area of roof openings for natural daylighting.

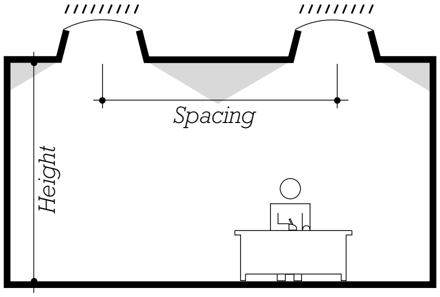
For example, reading the top chart, with a floor-to-ceiling height of 15 ft (4.5 m), small skylights should be spaced horizontally no more than 15 ft (4.5 m) center-to-center, roof monitors should be spaced no more than 22 ft (7 m), and large skylights should be spaced no more than 30 ft (9 m).

As a second example, reading the bottom chart, a 1000-sq-ft (93-m$^2$) hotel lobby area is to be illuminated with north-facing roof monitors. Using the table on page 150, we select Category C, simple orientation, as the appropriate lighting level. Reading the chart, we determine that 1000 sq ft (93 m$^2$) of floor area requires between 10 and 20 sq ft (0.9 and 1.9 m$^2$) of skylight area for full daylighting. Doubling the result for a north-facing monitor, our final answer is 20 to 40 sq ft (1.9 to 3.7 m$^2$) of glass area.

# TOPLIGHTING







Use the top chart to determine maximum horizontal spacing for skylights and roof monitors so as to maintain acceptably even lighting levels throughout a space.

Use the bottom chart to determine the skylight or roof monitor opening area necessary for daylighting various tasks over a given floor area. To determine the most appropriate illumination category for the space under consideration, see the table on page 150. For floor areas larger than those tabulated on the chart, read the chart using a smaller area and then multiply the result proportionally.

■ For skylights and south-facing roof monitors, read directly from the chart. For roof monitors facing other than south, use twice the indicated area.

■ For buildings in predominantly clear sky areas, read low in the ranges indicated on the chart. For buildings in heavily covered sky areas, read high in the indicated ranges. See page 141 to determine sky cover conditions for the project's location.

SECTION

# 4

# DESIGNING SPACES FOR MECHANICAL AND ELECTRICAL SERVICES

# 1

# SELECTING HEATING AND COOLING SYSTEMS FOR LARGE BUILDINGS

***This chapter will help you select a heating and cooling system for the preliminary design of a large building.***

# DESIGN CRITERIA FOR THE SELECTION OF HEATING AND COOLING SYSTEMS FOR LARGE BUILDINGS

| | |
|---|---|
| *If you wish to minimize the first cost of the heating and cooling system:* | Choose the simplest possible all-air system:<br>Single duct, constant air volume (pages 170–171)<br>or choose a system that involves no ductwork or piping:<br>Through-the-wall and packaged terminal units (page 178) |
| *If you wish to minimize operating cost and energy consumption:* | Choose systems that convert fuel to heating and cooling energy with maximum efficiency:<br>Variable air volume (pages 168–169)<br>Single duct, constant air volume (pages 170–171)<br>Hydronic convectors (pages 176–177)<br>or choose a system that uses ambient heat from the surrounding environment:<br>Closed-loop heat pump system (page 175)<br>or in medium-sized or smaller buildings, consider a passive system:<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Evaporative cooling (pages 231–232) |
| *If you wish to maximize control of air quality and air velocity:* | Choose one of the all-air heating systems:<br>Variable air volume (VAV) (pages 168–169)<br>VAV reheat (page 169)<br>VAV induction (page 169)<br>Dual-duct VAV (page 169)<br>Single duct, constant air volume (CAV) (pages 170–171)<br>CAV reheat (page 171)<br>Multizone (page 171) |
| *If you wish to maximize individual control over temperature in a number of rooms or zones:* | Choose a system that can react separately to a number of thermostats:<br>Variable air volume (VAV) (pages 168–169)<br>VAV reheat (page 169)<br>VAV induction (page 169)<br>Dual-duct VAV (page 169)<br>Constant air volume reheat (page 171)<br>Multizone (page 171)<br>Air-water induction (pages 172–173)<br>Fan-coil terminals (page 174)<br>Through-the-wall and packaged terminal units (page 178) |
| *If you wish to minimize system noise:* | Choose a system that operates at low air velocities and whose moving parts are distant from the occupied spaces, such as:<br>Any all-air system other than an induction system (pages 168–171)<br>Hydronic convectors (pages 176–177)<br>or in medium-sized or smaller buildings, consider a passive system:<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Evaporative cooling (pages 231–232) |

# DESIGN CRITERIA FOR THE SELECTION OF HEATING AND COOLING SYSTEMS FOR LARGE BUILDINGS

| | |
|---|---|
| *If you wish to minimize the visual obtrusiveness of the heating and cooling system:* | Choose a system that has minimal hardware in the occupied spaces of the building, such as:<br>Any all-air system (pages 168–171)<br>or in medium-sized or smaller buildings, consider a passive system:<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Evaporative cooling (pages 231–232) |
| *If you wish to maximize the flexibility of rental space and the adaptability of the heating and cooling system to space reconfiguration over time:* | Choose a central air system that has minimal hardware in the occupied spaces of the building and that can provide local or zoned control over temperature, such as:<br>Variable air volume (VAV) (pages 168–169)<br>VAV reheat (page 169)<br>Multizone (page 171)<br>or choose an all-water system that allows easy temperature control of individual spaces:<br>Fan-coil terminals (page 174)<br>Through-the-wall and packaged terminal units (page 178) |
| *If you wish to minimize the floor space used for the mechanical system or the floor-to-floor height of the building:* | Choose a local system that has no ductwork or piping, such as:<br>Through-the-wall and packaged terminal units (page 178)<br>or a system that minimizes the size of the ductwork or piping, such as:<br>Induction systems (pages 169, 172–173)<br>Hydronic convectors (pages 176–177)<br>or in medium-sized or smaller buildings, consider a passive system:<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Evaporative cooling (pages 231–232) |
| *If you wish to minimize maintenance requirements of the heating and cooling system:* | Choose systems that are very simple and have few moving parts in the occupied spaces of the building:<br>Variable air volume (pages 168–169)<br>Single duct, constant air volume (pages 170–171)<br>Hydronic convectors (pages 176–177)<br>or in medium-sized or smaller buildings, consider a passive system:<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Evaporative cooling (pages 231–232) |
| *If you wish to avoid having a chimney in the building:* | Choose systems that are electrically powered:<br>Any system that can use an electrically powered boiler (pages 168–177)<br>Through-the-wall and packaged terminal units (page 178)<br>or in medium-sized or smaller buildings, consider a passive system:<br>Passive solar heating (pages 222–224) |
| *If you wish to maximize the speed of construction:* | Choose systems that can be installed by a single trade, such as:<br>Through-the-wall and packaged terminal units (page 178) |

# HEATING AND COOLING SYSTEMS FOR LARGE BUILDINGS: SUMMARY CHART

| **GIVE SPECIAL CONSIDERATION TO THE SYSTEMS INDICATED IF YOU WISH TO:** | **Variable Air Volume (VAV) (page 168)** | **VAV Reheat (page 169)** | **VAV Induction (page 169)** | **Dual-Duct VAV (page 169)** | **Single Duct Constant Air Volume (CAV) (page 170)** | **CAV Reheat (page 171)** | **Multi-zone (page 171)** |
|---|---|---|---|---|---|---|---|
| Minimize first cost | | | | | ● | | |
| Minimize operating cost and energy consumption | ● | | | | ● | | |
| Maximize control of air velocity and air quality | ● | ● | ○ | ○ | ● | ○ | ○ |
| Maximize individual control over temperature | ● | ● | ○ | ○ | | ○ | ○ |
| Minimize system noise | ● | ● | | ○ | ● | ○ | ○ |
| Minimize visual obtrusiveness | ● | ● | ○ | ○ | ● | ○ | ○ |
| Maximize flexibility of rental space | ● | ● | | | | | ○ |
| Minimize floor space used for the heating and cooling systems | | | ○ | | | | |
| Minimize floor-to-floor height | | | ○ | | | | |
| Minimize system maintenance | ● | | | | ● | | |
| Avoid having a chimney | ●[a] | ●[a] | ○[a] | ○[a] | ●[a] | ○[a] | ○[a] |
| Maximize the speed of construction | | | | | | | |

● Frequently used
○ Less frequently used
[a] With electric boiler

# HEATING AND COOLING SYSTEMS FOR LARGE BUILDINGS: SUMMARY CHART

| | | | | | PASSIVE SYSTEMS | | | |
|---|---|---|---|---|---|---|---|---|
| **Air-Water Induction (page 172)** | **Fan-Coil Terminals (page 174)** | **Closed-Loop Heat Pumps (page 175)** | **Hydronic Convectors (heating only) (page 176)** | **Packaged Terminal Units or Through-the-Wall Units (page 178)** | **Passive Solar Heating (page 222)** | **Natural Ventilation Cooling (page 225)** | **Thermal Mass Cooling (page 228)** | **Evaporative Cooling (page 231)** |
| | | | | ● | | | | |
| | | ● | ● | | ● | ● | ● | ● |
| | | | | | | | | |
| ○ | ● | | | ● | | | | |
| | | | ● | | ● | ● | ● | ● |
| | | | | | ● | ● | ● | ● |
| | ● | | | ● | | | | |
| ○ | | | ● | ● | ● | ● | ● | ● |
| ○ | | | ● | ● | ● | ● | ● | ● |
| | | | ● | | ● | ● | ● | ● |
| ○[a] | ●[a] | ●[a] | ●[a] | ● | ● | | | |
| | | | | ● | | | | |

# SOME TYPICAL CHOICES OF HEATING AND COOLING SYSTEMS FOR LARGE BUILDINGS

| **OCCUPANCY** | **Variable Air Volume (VAV) (page 168)** | **VAV Reheat (page 169)** | **VAV Induction (page 169)** | **Dual-Duct VAV (page 169)** | **Single-Duct Constant Air Volume (CAV) (page 170)** | **CAV Reheat (page 171)** | **Multi-zone (page 171)** |
|---|---|---|---|---|---|---|---|
| Apartments | | | | | | | |
| Arenas, Exhibition Halls | ●[a] | | | | ●[a] | | |
| Auditoriums, Theaters | ●[a] | | | | ●[a] | | ●[a] |
| Factories | ●[a] | ● | | | ●[a] | | ●[a] |
| Hospitals | ● | ● | | ● | | ● | ● |
| Hotels, Motels, Dormitories | ● | | | | | | |
| Laboratories | ● | ● | | ● | ● | ● | |
| Libraries | ● | | | | | | ● |
| Nursing Homes | ● | | | | | | |
| Offices | ●[a] | | ● | | | | ●[a] |
| Places of Worship | ● | | | | ● | | ● |
| Schools | ●[a] | ● | | | | | |
| Shopping Centers | ●[a] | | | | | | ●[a] |
| Stores | ●[a] | | | | | | ●[a] |

● Frequently used
○ Less frequently used
[a] Sometimes installed as packaged systems

# SOME TYPICAL CHOICES OF HEATING AND COOLING SYSTEMS FOR LARGE BUILDINGS

| | | | | | PASSIVE SYSTEMS | | | |
|---|---|---|---|---|---|---|---|---|
| Air-Water Induction (page 172) | Fan-Coil Terminals (page 174) | Closed-Loop Heat Pumps (page 175) | Hydronic Convectors (heating only) (page 176) | Packaged Terminal Units or Through-the-Wall Units (page 178) | Passive Solar Heating (page 222) | Natural Ventilation Cooling (page 225) | Thermal Mass Cooling (page 228) | Evaporative Cooling (page 231) |
| | ● | ● | ● | ● | ○ | ○ | ○ | ○ |
| | ● | | | | | | | |
| | | | | | | | | |
| ○ | ● | | ● | | | | | |
| ○ | ● | | | | | | | |
| ○ | ● | ● | | ● | | ○ | ○ | ○ |
| | | | | | | | | |
| | | | | | ○ | ○ | ○ | ○ |
| | ● | | | ● | | | | |
| ○ | | | ● | | ○ | ○ | ○ | ○ |
| | | | ● | | ○ | ○ | ○ | |
| | ● | | | | ○ | ○ | ○ | ○ |
| | | | | | | | | |
| | | | | | | | | |

## ZONING A BUILDING FOR HEATING AND COOLING

Before attempting to select a heating and cooling system, rough out a zoning scheme for the building, establishing zones that differ from one another in their thermal conditioning requirements and will be controlled separately. Sometimes a zone should be no larger than a single room (a classroom, a hotel room). Sometimes a number of spaces with similar thermal requirements can be grouped into a larger zone (a group of offices that are occupied during the day but not at night; a group of galleries in a museum). Sometimes rooms must be put in separate zones because they have differing requirements for air quality or temperature (locker rooms in a gymnasium complex, cast dressing rooms in a theater). Sometimes different zones must be established to deal effectively with different rates of internal generation of heat (a kitchen in a restaurant or dining hall, a computer room in a school, a metal casting area in an industrial building).

Buildings in which solar heat gain through windows is a major component of the cooling load need to be zoned according to the various window orientations of the rooms. In commercial buildings where each tenant will be billed separately for heating and cooling costs, each tenant space will constitute a separate zone. A large business or mercantile building might be divided into several large zones of approximately equal size to fit the capacities of the fans and ductwork or the capacities of packaged air conditioning systems. A multiuse building may incorporate parking, retail shops, lobbies, offices, and apartments, each requiring a different type of heating and cooling system.

The zoning of a building is significant in the early stages of design because it may suggest a choice of heating and cooling system: Room-by-room zoning suggests an all-water fan-coil system or packaged terminal units for an apartment building, for example, meaning that the building does not have to be designed to accommodate major ductwork. Zoning may also have an impact on where the major equipment spaces are placed. It often makes sense to put major equipment on the "seam" between two zones. An example of this might be placing the major heating and cooling equipment on the second or third floor of a multiuse downtown building, above retail and lobby spaces and below multiple floors of office space.

## CENTRAL SYSTEMS VERSUS LOCAL SYSTEMS

In a central system, heat is supplied to a building or extracted from it by large equipment situated in one or several large mechanical spaces. Air or water is heated or cooled in these spaces and distributed to the inhabited areas of the building by ductwork or piping to maintain comfortable temperatures.

In a local system, independent, self-contained pieces of heating and cooling equipment are situated throughout the building, one or more in each room.

Central systems are generally quieter and more energy efficient than local systems and offer better control of indoor air quality. Central equipment tends to last longer than local equipment and is more convenient to service. Local systems occupy less space in a building than central systems because they do not require dedicated mechanical spaces and extensive ductwork or piping. They are often more economical to buy and install. They can be advantageous in buildings that have many small spaces requiring individual temperature control.

On pages 168–177, alternative choices of central heating and cooling systems for large buildings are described. Local systems are described on page 178.

## FUELS

Heating and cooling equipment in large buildings may be powered by oil, gas, electricity, steam, or hot water. In central areas of many large cities, utility-generated pipeline steam is available. In some large building complexes, such as university campuses, steam or hot water is furnished to each structure, along with chilled water for cooling, via underground pipelines from a single central boiler/chiller plant. Steam and hot water, where available, are ideal energy sources for heating and cooling, because no chimney is needed and the necessary heat exchange equipment for steam or hot water is more compact than the fuel-burning boilers that would otherwise be required.

Electricity can also be an attractive energy source, because it is clean, it is distributed through compact lines, and electrical equipment tends to be quieter and smaller than fuel-burning equipment. However, when the efficiencies of remote electrical power generation and distribution are considered, electricity converted directly into heat is less efficient in comparison to systems that rely on the burning of oil or gas on site. In most areas, such electric heating is also more costly. Gas burns cleanly and requires no on-site storage of fuel.

In areas where it is more economical than gas, fuel oil is favored despite its need for on-site storage tanks.

## MEANS OF DISTRIBUTION

The distribution of heating and cooling energy in central systems involves the circulation of air, water, or both to the inhabited spaces.

- In *all-air systems*, central fans circulate conditioned air to and from the spaces through long runs of ductwork.
- In *air and water systems*, air is ducted to each space. Heated water and chilled water are also piped to each space, where they are used to modify the temperature of the circulated air at each outlet to meet local demands. Air and water systems circulate less air than all-air systems, which makes them somewhat more compact and easier to house in a building.
- In *all-water systems*, air is circulated locally rather than from a central source, so ductwork is eliminated. Only heated water and chilled water are furnished to each space. The water piping is much smaller than equivalent ductwork, making all-water systems the most compact of all.

All-air systems offer excellent control of interior air quality. The central air-handling equipment can be designed for precise control of fresh air, filtration, humidification, dehumidification, heating, and cooling. When the outdoor air is cool, an all-air system can switch to an economizer cycle, in which it cools the building by circulating a maximum amount of outdoor air. All-air systems concentrate maintenance activities in unoccupied areas of the building because there are no water pipes, condensate drains, valves, fans, or filters outside the mechanical equipment rooms.

Air-and-water and all-water systems, besides saving space, can offer better individual control of temperature in the occupied spaces than some all-air systems, but they are inherently more complicated, and more maintenance activity must be carried out in the occupied spaces.

## SELECTING HEATING AND COOLING SYSTEMS FOR LARGE BUILDINGS

The next few pages summarize the choices of heating and cooling systems for large buildings. To determine the space required by any system, look first at the list of major components that is included with each system description. The dimensions of any components that are unique to the system are given immediately following this list. Components that are common to more than one system may be sized using the charts on pages 210–213.

## Description

Air is conditioned (mixed with a percentage of outdoor air, filtered, heated or cooled, and humidified or dehumidified) at a central source. Supply and return fans circulate the conditioned air through ducts to the occupied spaces of the building. At each zone, a thermostat controls room temperature by regulating the volume of air that is discharged through the diffusers in that zone.

## Typical Applications

VAV is the most versatile and most widely used system for heating and cooling large buildings.

## Advantages

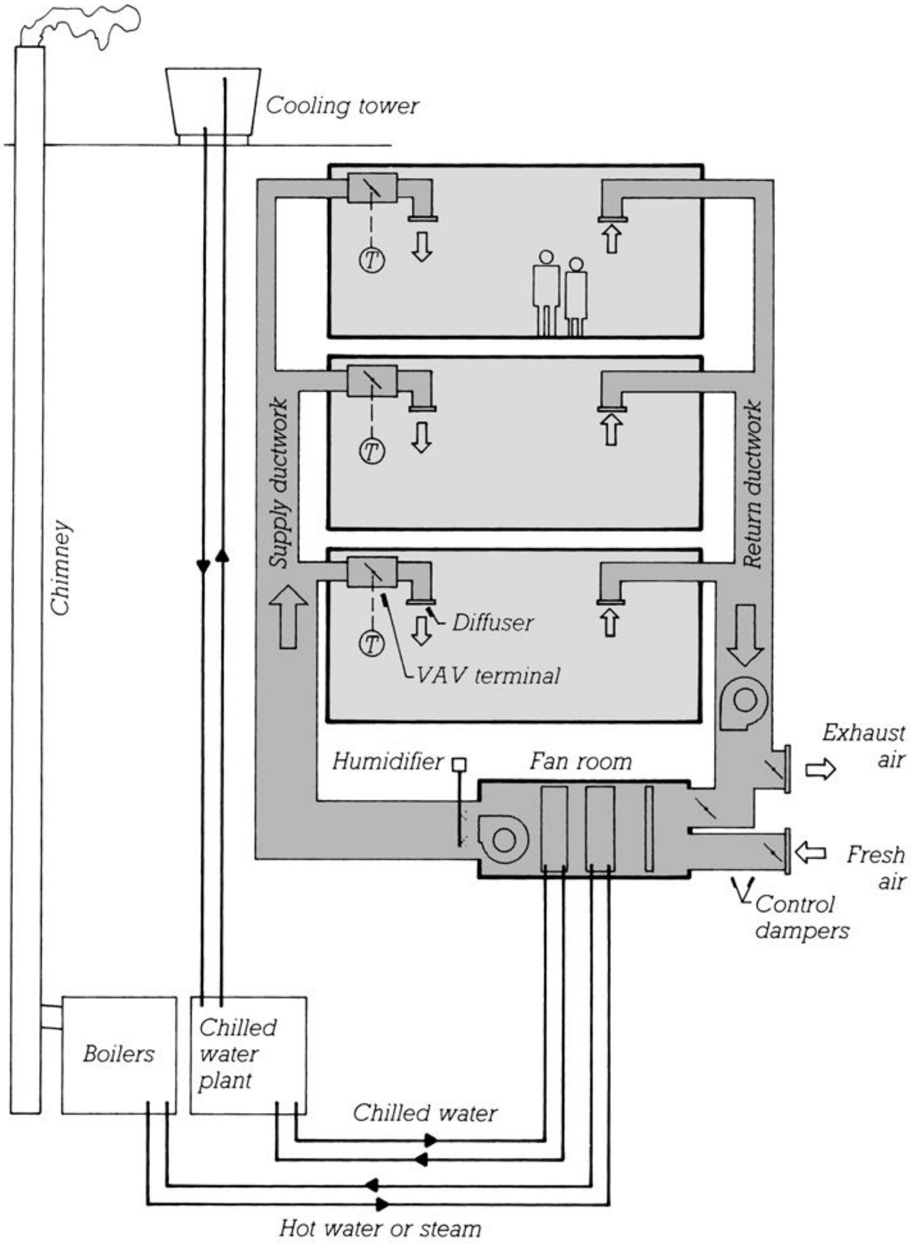
This system offers a high degree of local temperature control at moderate cost. It is economical to operate and virtually self-balancing.

## Disadvantages

VAV is limited in the range of heating or cooling demand that may be accommodated within a single system. When one area of a building needs heating while another needs cooling, a VAV system cannot serve both areas without help from a secondary system (see Variations, following).

## Major Components

Boilers and chimney, chilled water plant, cooling tower, fan room, outdoor fresh air and exhaust louvers, vertical supply and return ducts, horizontal supply and return ducts,



SINGLE DUCT, VARIABLE AIR VOLUME (VAV)

a VAV control box for each zone, supply diffusers, return grilles. (For an illustration of typical diffusers and grilles, see page 209.)

Alternately, in buildings of moderate size, a packaged system may be used in place of all components other than ducts, VAV control boxes, diffusers, and grilles. A single-packaged system, incorporating all central components in a single metal box, may be installed on the roof or outside an exterior wall, or a split-packaged system may be installed, with a compressor and condensing unit in an outdoor box and an air handling unit in an indoor box. Multiple packaged systems are often used to serve buildings that are large in horizontal extent. For more detailed information on packaged units, see pages 186–187.

## Sizing the Components

The VAV control box is usually concealed above a suspended ceiling. It is approximately 8 to 11 in. (200 to 280 mm) high for zones up to 1500 sq ft (150 m$^2$) in area and up to 18 in. (460 mm) high for zones up to 7000 sq ft (700 m$^2$). Its horizontal dimensions vary with its capacity, up to a maximum length of about 5 ft (1.5 m). To size the other components of a VAV system, use the charts on pages 210–213.

## Variations

**1.** In buildings with large areas of windows, VAV is often combined with a second system around the perimeter of the building to deal with the large differences in heating and cooling demand between interior and perimeter rooms. The second system is most commonly either an induction system (see variation 3, following) or hydronic convectors (see pages 176–177).

**2.** A *single duct variable air volume reheat system* is identical to the basic VAV system up to the point at which the air enters the local ductwork for each zone. In a reheat system, the air then passes through a reheat coil before it is distributed to the local diffusers. The reheat coil may be either an electric resistance coil or a pipe coil that carries hot water circulated from the boiler room. A local thermostat controls the flow of water or electricity through the reheat coil, allowing for close individual control of room temperature. This variation can overcome the inability of VAV systems to cope with a wide range of heating and cooling demands. VAV reheat systems are more energy-efficient than constant air volume reheat systems (page 171) because in the VAV systems the reheat coil is not activated unless the VAV system is incapable of meeting the local requirement for temperature control, and a much smaller amount of tempered air is circulated.

**3.** In the *variable air volume induction system*, a smaller volume of conditioned air is circulated through small high-velocity ducts from a central source. Each outlet is designed so that the air discharging from the duct continually pulls air from the room into the outlet, mixes it with air from the duct, and discharges the mixture into the room. This variation is used where limited space is available for ducts. It is also used to maintain a sufficient level of air movement in spaces that do not have a high demand for heating or cooling.

**4.** In a *dual duct variable air volume system*, paired side-by-side ducts carry both heated and cooled air to each zone in the building. At each zone, the two airstreams are proportioned and mixed under thermostatic control to achieve the desired room temperature. This variation gives excellent local temperature control, but it requires an expensive and space-consuming dual system of ductwork, and it is not energy-efficient.

# CENTRAL ALL-AIR SYSTEMS: SINGLE DUCT, CONSTANT AIR VOLUME (CAV)

### Description

Air is conditioned (mixed with a percentage of outdoor air, filtered, heated or cooled, and humidified or dehumidified) at a central source. Supply and return fans circulate the air through ducts to the occupied spaces of the building. A master thermostat controls the central heating and cooling coils to regulate the temperature of the building.

### Typical Applications

Spaces that have large open areas, few windows, and uniform loads, such as lobbies, department stores, theaters, auditoriums, and exhibition halls.

### Advantages

This system offers a high degree of control of air quality. It is comparatively simple and easy to maintain.

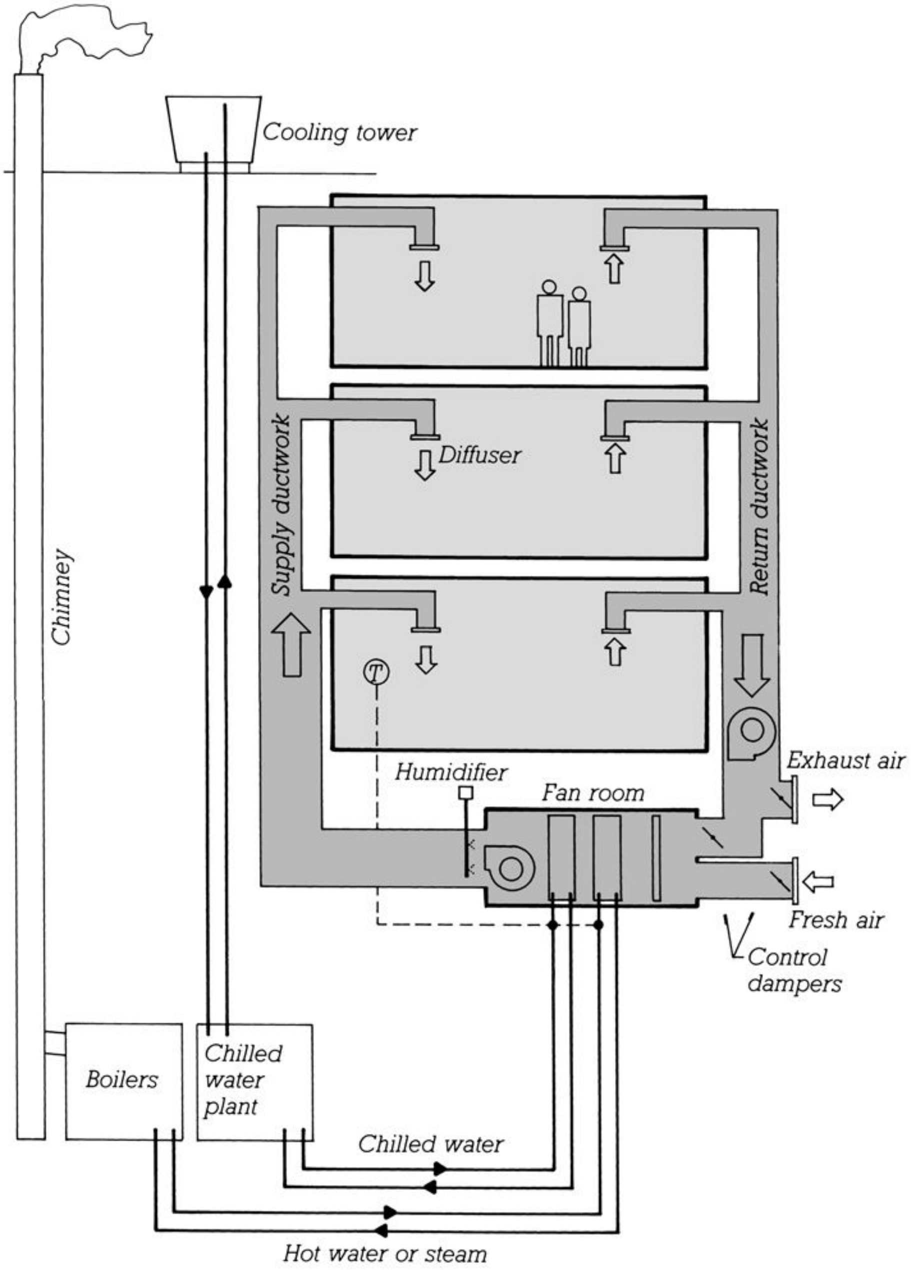
### Disadvantages

The entire area served by the system is a single zone, with no possibility for individual temperature control.

### Major Components

Boilers and chimney, chilled water plant, cooling tower, fan room, outdoor fresh air and exhaust louvers, vertical supply and return ducts, horizontal supply and return ducts, supply diffusers, and return grilles. (For an illustration of typical diffusers and grilles, see page 209.)

Alternately, in buildings of moderate size, a packaged system may be used in place of all components other than ducts, diffusers, and grilles. A *single-packaged system*, incorporating all central components in a single metal box, may be installed on the roof or outside an exterior wall, or a *split-packaged system* may be installed, with a compressor and a condensing unit in an outdoor box and an air handling unit in an indoor box. Multiple packaged systems are often used to serve buildings that are large in horizontal extent. For more detailed information on packaged units, see pages 186–187.



**SINGLE DUCT, CONSTANT AIR VOLUME (CAV)**

### Sizing the Components

For the dimensions of these components, see the charts on pages 210–213.

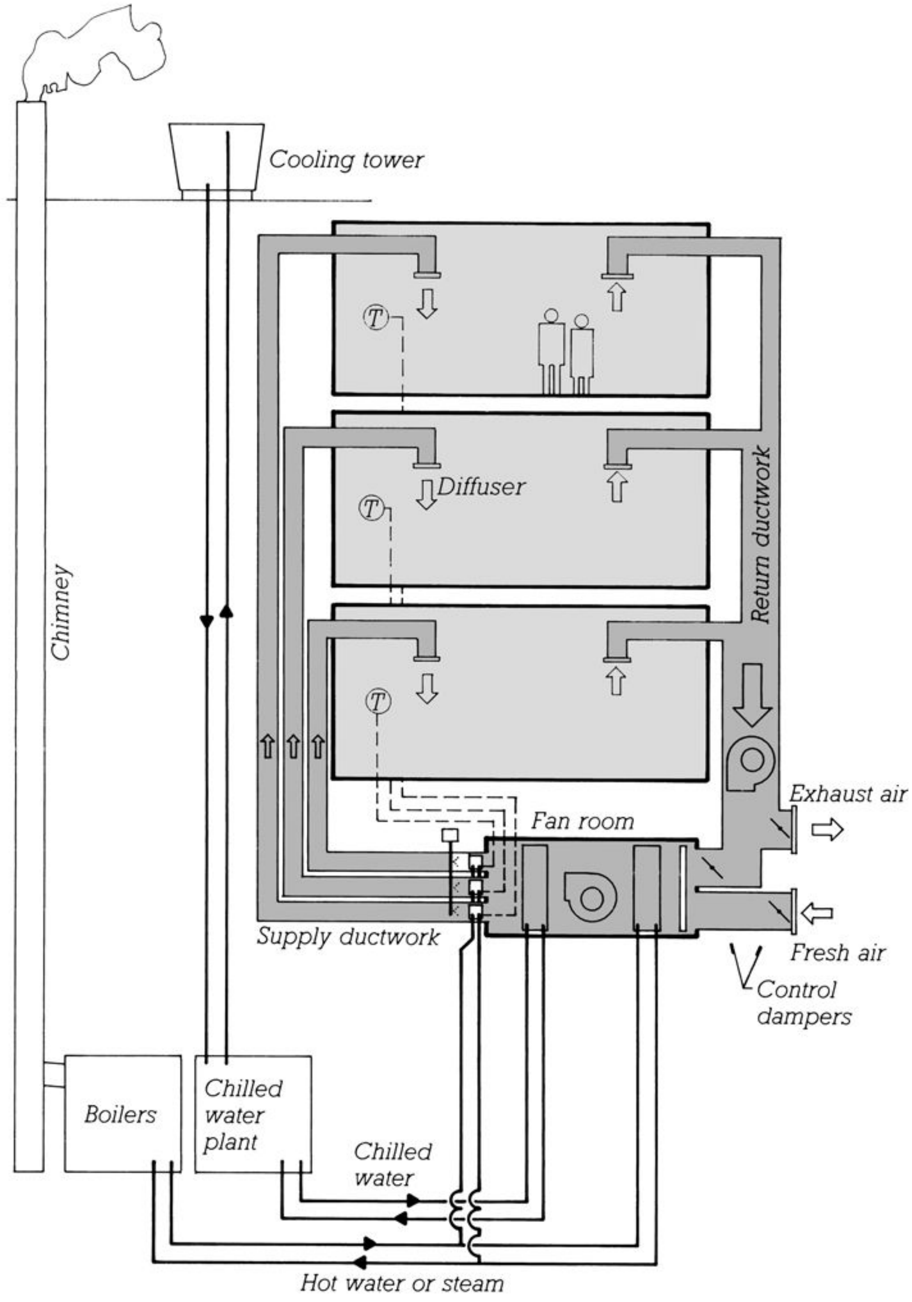
# CENTRAL ALL-AIR SYSTEMS: SINGLE DUCT, CONSTANT AIR VOLUME (CAV)

## Variations

**1.** A *furnace* is an indoor unit that incorporates a source of heat and an air-circulating fan into a single metal box. The source of heat may be a gas burner, an oil burner, an electric resistance coil, or a heat pump coil. Cooling coils may also be incorporated if desired. The capacity of furnaces is limited to such an extent that they are used mostly in single-family houses and other very small buildings; multiple furnaces are sometimes used to heat and cool somewhat larger buildings. For a more extended discussion of furnaces, see pages 243–245.

**2.** A single duct, *constant air volume reheat system* is identical to the CAV system first described up to the point at which the air enters the local ductwork for each zone. In reheat systems, the air then passes through a reheat coil. The reheat coil may carry hot water or steam piped from the boiler room, or it may be an electric resistance coil. A local thermostat controls the temperature of the reheat coil, allowing for close individual control of room temperature. Reheat systems are typically used in situations requiring precise temperature control and constant airflow, such as laboratories, hospital operating rooms, or specialized industrial processes. Because CAV reheat systems are inherently wasteful of energy, first cooling air and then heating it, they are not often specified for new buildings.

**3.** In the *multizone system*, several ducts from a central fan serve several zones. In one type of multizone system, dampers blend hot and cold air at the fan to send air into each duct at the temperature requested by the thermostat in that zone. In another type (the one illustrated here), reheat coils in the fan room regulate the temperature of the air supplied to each zone. Multizone systems require a large amount of space for ductwork in the vicinity of the fan, so they are generally restricted to a small number of zones with short runs of ductwork. Packaged multizone units are also available.



MULTIZONE SYSTEM

# CENTRAL AIR AND WATER SYSTEMS: AIR-WATER INDUCTION SYSTEM

## Description

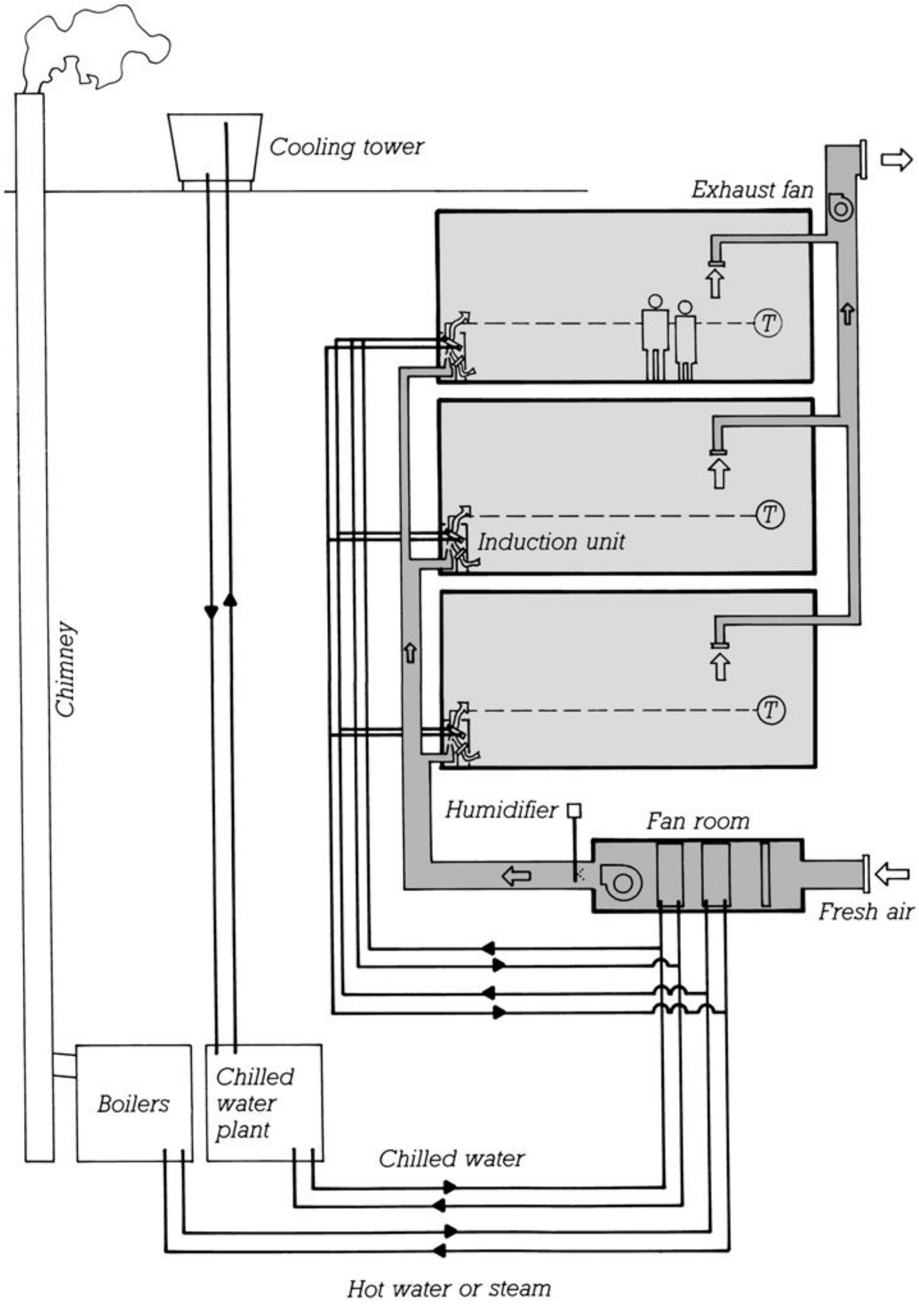
Fresh air is heated or cooled, filtered, and humidified or dehumidified at a central source and circulated in small high-velocity ducts to the occupied spaces of the building. Each outlet is designed so that the air discharging from the duct (called *primary air*) draws a much larger volume of room air through a filter. The mixture of primary air and room air passes over a coil that is either heated or cooled by *secondary water* piped from the boiler room and chilled water plant. The primary air (about 15% to 25% of the total airflow through the outlet) and the heated or cooled room air that has been induced into the outlet (75% to 85% of the total airflow) are mixed and discharged into the room. A local thermostat controls water flow through the coil to regulate the temperature of the air. Condensate that drips from the chilled water coil is caught in a pan and removed through a system of drainage piping (not shown in the accompanying diagram).

## Typical Applications

Interior spaces of buildings with a wide range of heating and cooling loads where close control of humidity is not required, especially office buildings.

## Advantages

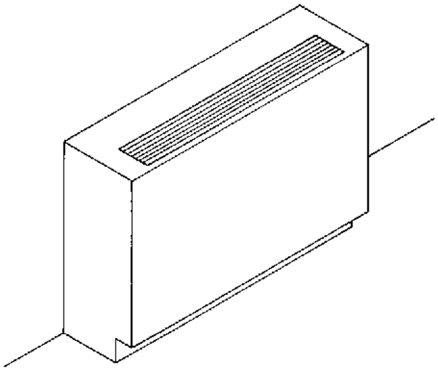
This system offers good local temperature control. Space requirements for ductwork and fans are less than those for all-air systems. There are no fans in the occupied spaces.



AIR-WATER INDUCTION SYSTEM

## Disadvantages

This is a relatively complicated system to design, install, maintain, and manage. It tends to be noisy, and it is very inefficient in its use of energy. Humidity cannot be closely controlled. It is rarely designed or specified today.



AIR-WATER INDUCTION UNIT

## Major Components

Boilers and chimney, chilled water plant, cooling tower, fan room, outdoor fresh air and exhaust louvers, vertical supply and return ducts, horizontal supply and return ducts, vertical supply and return piping, horizontal supply and return piping, condensate drainage piping, air-water induction units. The water piping to each unit may consist of two, three, or four pipes, depending on whether a single coil is used for both heating and cooling or separate coils are provided for each. An additional pipe is required for condensate drainage.

## Sizing the Components

Induction units are usually sized to fit beneath a window. Heights range from 25 to 28 in. (635 to 710 mm), depths from 9 to 12 in. (230 to 305 mm), and lengths from 30 to 84 in. (760 to 2130 mm). For the dimensions of the other components of the system, see the charts on pages 210–213.

## Variations

*Fan-coil units with primary air supply* are similar to induction units, but use a fan to blow air through the coils instead of relying on the induction action of the primary airstream to circulate air from the room. The advantage of the fan-coil unit is that it can continue to circulate air even when the primary air is turned off. The primary air can be supplied through either the fan-coil unit or a separate diffuser.

# CENTRAL ALL-WATER SYSTEMS: FAN-COIL TERMINALS

## Description

Hot and/or chilled water are piped to fan-coil terminals. At each terminal, a fan draws a mixture of room air and outdoor air through a filter and blows it across a coil of heated or chilled water and then back into the room. A thermostat controls the flow of hot and chilled water to the coils to control the room temperature. Condensate that drips from the chilled water coil is caught in a pan and removed through a system of drainage piping (not shown in this diagram). In most installations, the additional volume of air brought from the outdoors is used to pressurize the building to prevent infiltration or is exhausted through toilet exhaust vents.

## Typical Applications

Buildings with many zones, all located on exterior walls, such as schools, hotels, motels, apartments, and office buildings.

## Advantages

No fan rooms or ductwork spaces are required in the building. The temperature of each space is individually controlled.

## Disadvantages

Humidity cannot be closely controlled. This system requires considerable maintenance, most of which must take place in the occupied space of the building.

## Major Components

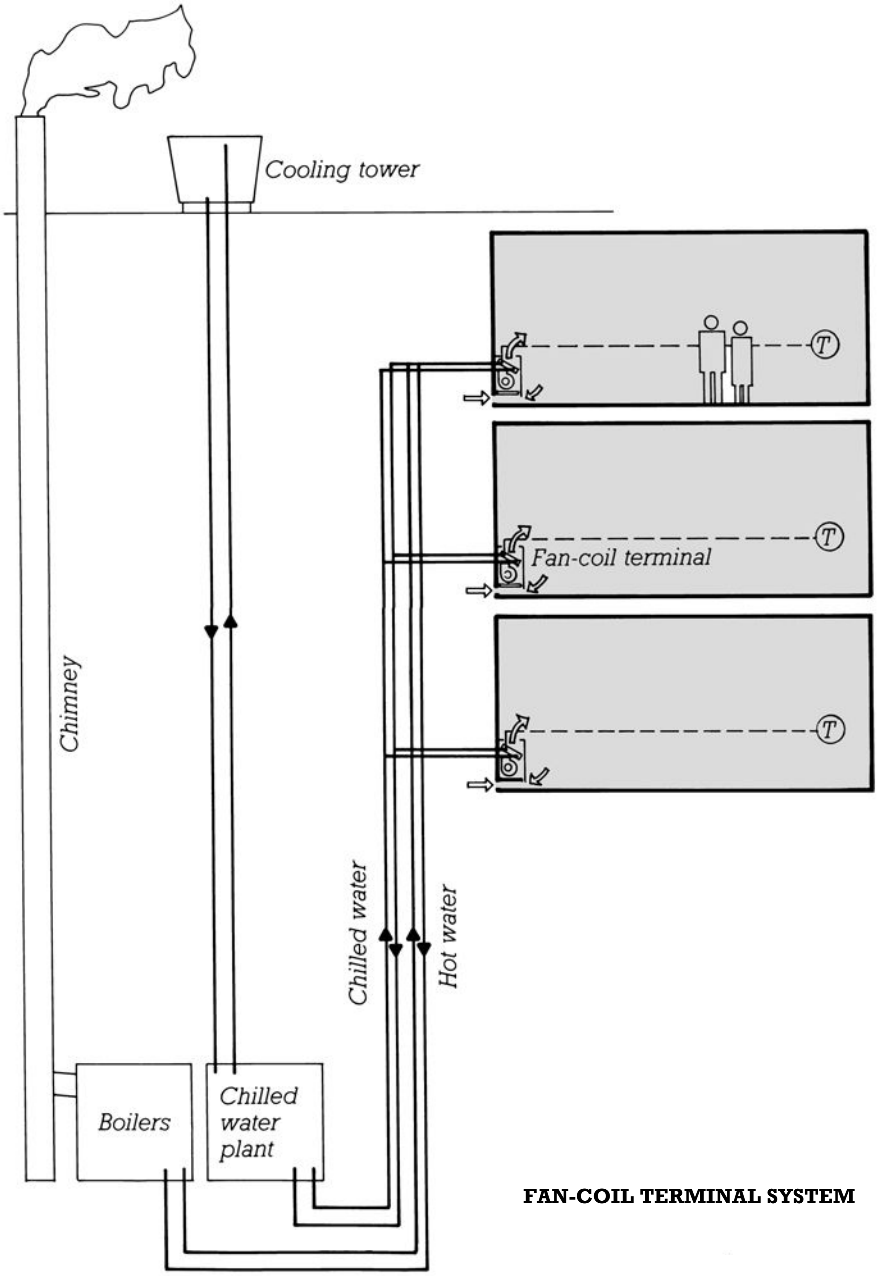
Boilers and chimney, chilled water plant, cooling tower, vertical supply and return piping, horizontal supply and return piping, condensate drainage piping, fan-coil terminals, outside air grilles.

## Sizing the Components

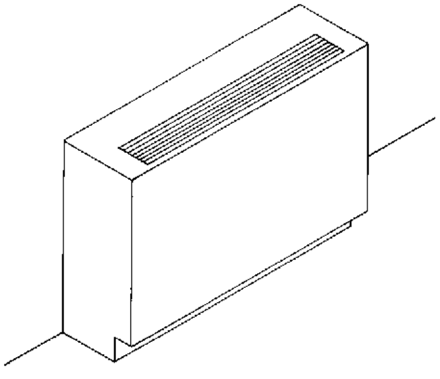
Fan-coil terminals are usually sized to fit beneath a window. Heights range from 25 to 28 in. (635 to 710 mm), depths from 9 to 12 in. (230 to 305 mm), and lengths from 30 to 84 in. (760 to 2130 mm). For the dimensions of the other components of the system, see the chart on pages 210–211.

## Variations

Fan-coil terminals are also manufactured in a horizontal ceiling-hung configuration and in a tall, slender configuration for mounting in vertical chases.



FAN-COIL TERMINAL SYSTEM



FAN-COIL TERMINAL

# CENTRAL ALL-WATER SYSTEMS: CLOSED-LOOP HEAT PUMPS

### Description

A water-to-air heat pump unit in each space provides heating, cooling, and fresh air. The water source for all the heat pumps in the building circulates in a closed loop of piping. Control valves allow the water source to circulate through a cooling tower in the summer and a boiler in the winter, and to bypass both the boiler and the cooling tower in spring and fall and at any other time when the heating and cooling needs of the various rooms in the building balance one another.

### Typical Applications

Hotels containing chronically overheated areas (kitchens, laundry, assembly rooms, restaurants).

### Advantages

This is an efficient system in which heat extracted from chronically overheated areas can be used to heat underheated areas (e.g., guest rooms).

### Disadvantages

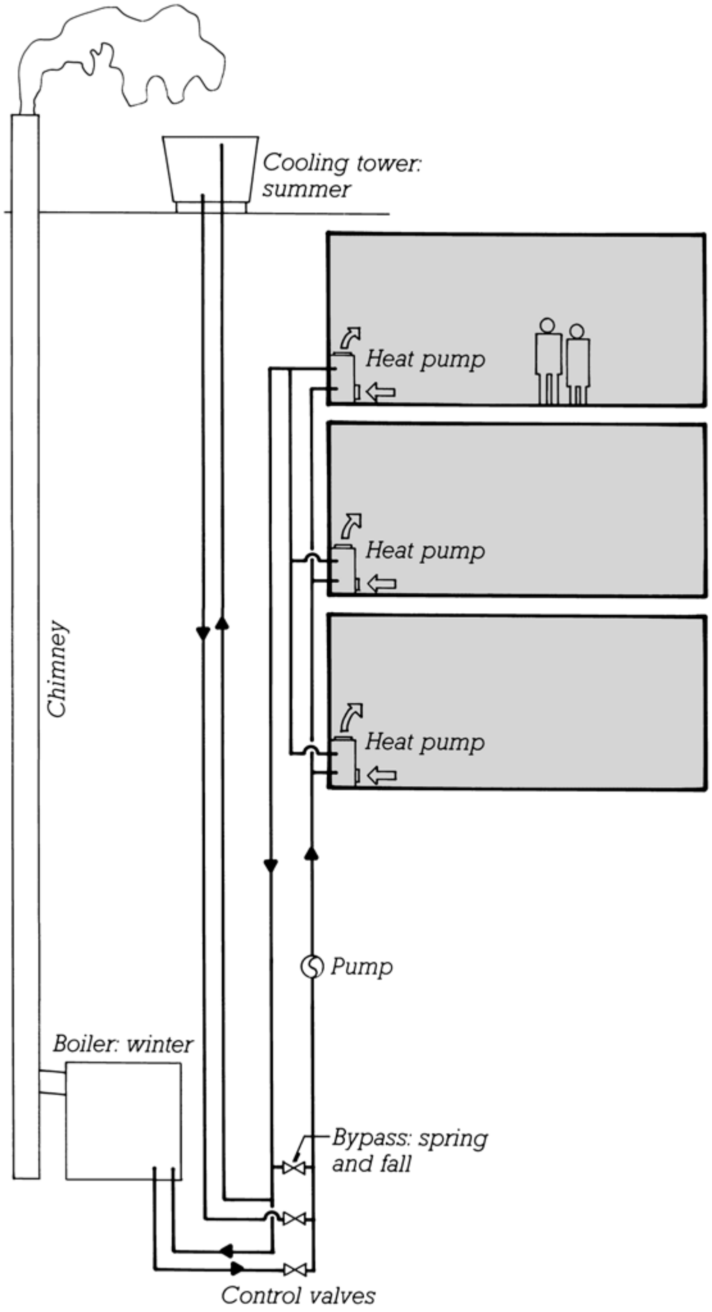
This is an expensive system to install, and careful economic analysis is needed to determine if the high installation costs can be balanced by energy savings. The heat pumps require that much of the routine maintenance take place in the occupied spaces.

### Major Components

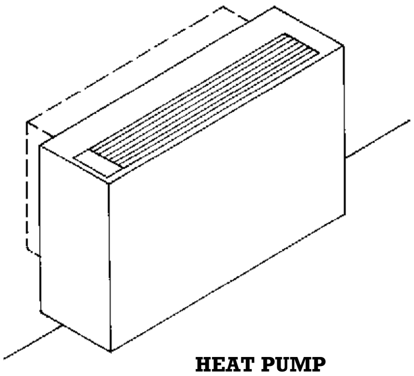
Heat pump units, boiler room, cooling tower.

### Sizing the Components

The heat pumps may be located above a dropped ceiling over the bathroom and dressing areas in hotel rooms or below windows. A typical under-window heat pump unit is approximately 30 in. (760 mm) high, 12 in. (305 mm) deep, and 60 in. (1525 mm) long. An above-ceiling unit has approximately the same dimensions, with the 12-in. (305-mm) dimension vertical. For the dimensions of the other components of the system, see the chart on pages 210–211.



**CLOSED-LOOP HEAT PUMP SYSYTEM**



**HEAT PUMP**

## Description

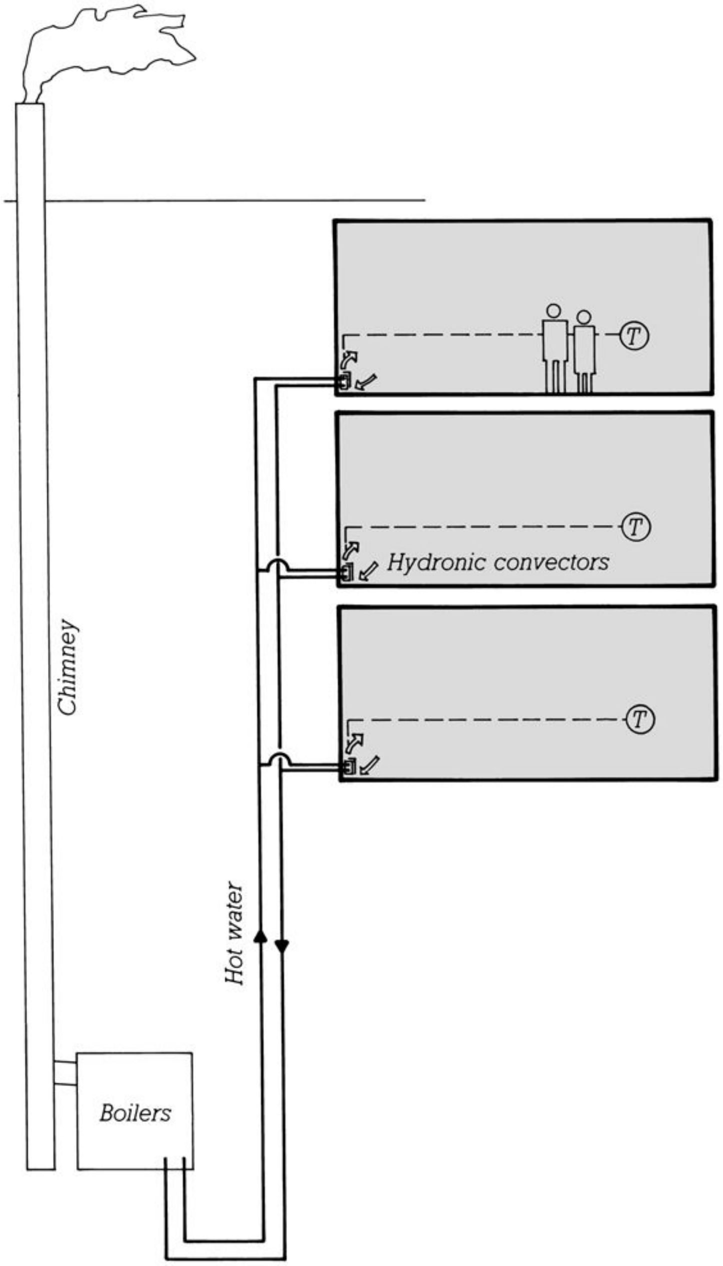
Hot water from the boiler room is circulated through fin-tube convectors, which are horizontal pipes with closely spaced vertical fins, usually mounted in a simple metal enclosure with an air inlet opening below and outlet louvers above. The heated fins, working by convection, draw cool room air into the enclosure from below, heat it, and discharge it out the top.

## Typical Applications

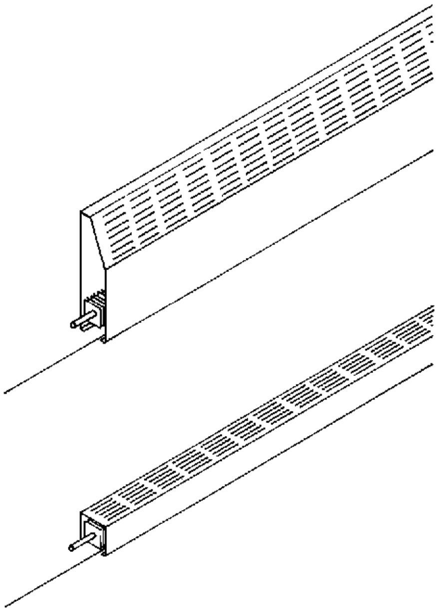
Hydronic convectors are used alone in buildings where cooling is not required and where ventilation may be accomplished by opening windows or through a supplemental ventilation system. They are also used as a supplemental source of heat in combination with other heating and cooling systems.

## Advantages

This is an economical system to install and operate. It provides excellent comfort during the heating season. Convectors are available in configurations ranging from continuous horizontal strips to cabinet units, either recessed or surface-mounted. Local control of temperature is possible through thermostatically controlled zone pumps or zone valves; through self-contained, thermostatically controlled valves at each convector; or, in some types of convectors, through manually controlled dampers.



HYDRONIC CONVECTORS



**HYDRONIC FIN-TUBE CONVECTORS**

## Disadvantages

This is a system for heating only. Cooling, humidity control, and ventilation must be provided by separate means.

## Major Components

Boilers and chimney, vertical supply and return piping, horizontal supply and return piping, convectors.

## Sizing the Components

Hydronic convectors usually run continuously around the perimeter of a building. Each convector contains one or sometimes two continuous fin-tubes. The sheet metal enclosures for the fin-tubes are available in a variety of configurations. The smallest is about 5 in. (127 mm) square in cross section and should be mounted at least 4 in. (100 mm) above the floor. Enclosures up to 28 in. (710 mm) high and 6 in. (152 mm) deep are often used for improved thermal performance. The top of the enclosure contains small louvers and may be sloping or flat. For the dimensions of the other components of a hydronic heating system, see the chart on pages 210–211.

## Variations

**1.** Hydronic heating is useful in buildings down to the scale of single-family residences. See pages 246–247.

**2.** In spaces where insufficient perimeter is available for convectors or where the presence of convectors is undesirable, fan-forced unit heaters may be used. These are housed in metal cabinets that may be recessed in a wall, mounted on the surface of a wall, or suspended from the ceiling structure. Each heater contains a hot-water coil fed from the boiler room and an electric fan to circulate air across the coil. Unit heaters are very compact in relation to their heating capacity compared to convectors.

# LOCAL SYSTEMS: PACKAGED TERMINAL UNITS AND THROUGH-THE-WALL UNITS

## Description

One or several through-the-wall units or packaged terminal units are mounted on the exterior wall of each room. Within each unit, an electric-powered compressor and evaporator coil provide cooling capability. Heating is supplied either by electric resistance coils or by utilizing the compressor in a reversible cycle as a heat pump. A fan draws indoor air through a filter, adds a portion of outdoor air, passes the air across the cooling and heating coils, and blows it back into the room. Another fan circulates outdoor air independently through the unit to cool the condensing coils (and, in a heat pump cycle, to furnish heat to the evaporator coils). A control thermostat is built into each unit.

There are several alternative types of equipment that fit into this category. *Packaged terminal units* are contained primarily in an indoor metal cabinet that fits beneath a window; they are connected to outdoor air with a wall box and an outdoor grille. *Through-the-wall units* are contained in a rectangular metal box that is mounted directly in an opening in the exterior wall of the building. A variation of the through-the-wall unit is the familiar *window-mounted unit*, used only for low-cost retrofitting of existing buildings. The only service distribution to any of these types of units is an electric cable or conduit.

## Typical Applications

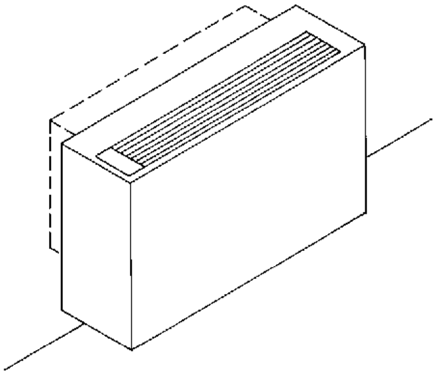
Apartments, dormitories, motels, hotels, office buildings, schools, nursing homes.

**TYPICAL DIMENSIONS OF PACKAGED TERMINAL UNITS AND THROUGH-THE-WALL UNITS**

| | Width | Depth | Height |
|---|---|---|---|
| Packaged terminal units | 43"<br>(1100 mm) | 14"–20"<br>(360–510 mm) | 16"<br>(410 mm) |
| Through-the-wall units | 24–26"<br>(610–660 mm) | 17"–30"<br>(430–760 mm) | 16"–18"<br>(410–460 mm) |

## Advantages

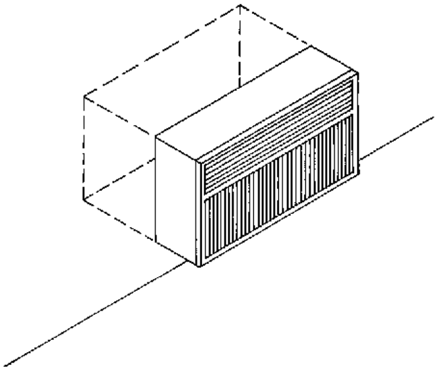
Units are readily available and easily installed. Initial costs are often lower than those for central systems. Each room has individual control of temperature. No building space is utilized for central equipment, ductwork, or piping. Operating costs may be lower than those for central systems in buildings in which not all spaces need to be heated or cooled all the time, such as motels.



PACKAGED TERMINAL UNIT

## Disadvantages

Maintenance costs are high and equipment life is relatively short. Maintenance must be carried out in the occupied spaces. The equipment is often noisy and inefficient. Air distribution can be uneven. Wintertime humidification is not possible. Operating costs are high in areas with very cold winters and costly electricity. Through-the-wall and window-mounted units can be unsightly.



THROUGH-THE-WALL UNIT

## Major Components

Packaged terminal units or through-the-wall units. Typical dimensions of these units are given in the table above.

# 2

# CONFIGURING AND SIZING MECHANICAL AND ELECTRICAL SERVICES FOR LARGE BUILDINGS

***This chapter will help you lay out the necessary spaces for mechanical and electrical equipment in a preliminary design for a large building.***

The major equipment spaces for a large building are discussed in alphabetical order on the pages that follow.

## BOILER ROOM AND CHIMNEY

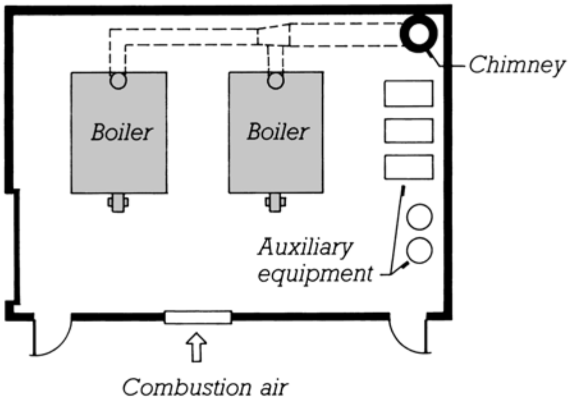
The boiler room produces hot water or, less commonly, steam to heat the building and to heat domestic water. Sometimes steam is also used to power absorption chilling equipment. A boiler room for a large building normally contains at least two boilers so that one may be in service even if the other is being cleaned or repaired. All boilers are connected to a single chimney. The boiler room may be placed anywhere in a building; common locations are a basement, a mechanical room on grade, a mechanical floor, or the roof. It should be on an outside wall because it needs an intake grille for combustion air and a door or removable panel to allow for removal and replacement of the boilers. Because of the noise and heat it gives off, a boiler room should be placed below or adjacent to areas such as loading docks and lobbies that will not be adversely affected. It is helpful to locate the boiler room next to the chilled water plant; the two facilities are often combined in a single room. Hot water supply and return pipes run from the boilers through vertical shafts to reach the other floors of the building.

Boilers and their associated equipment create very heavy floor loadings that need to be taken into account when designing the supporting structure. In many cases, building codes require that the boiler room enclosure be fire-resistance rated or the room itself must be sprinklered.

Boilers may be fueled by gas, electricity, or oil. Electric boilers, which generally are economical only in areas where electricity costs are very low, eliminate the need for combustion air inlets and a chimney. Generally, a 2-week supply of fuel for an oil-fired boiler is stored in tanks in or near the building. The filler pipes must be accessible to oil delivery vehicles. These tanks are usually buried next to the building if space permits. If the tanks are inside the building, they must be installed in a naturally ventilated room that is designed so that it can contain the full contents of a tank and keep the contents from escaping into the building if the tank should leak. A basement location on an outside wall is preferred. Oil for a boiler on an upper floor of a building is pumped up a shaft through a pipe from the tanks below.

An approximate floor area for a boiler room may be determined using the chart on pages 210–211. In larger buildings, a long, narrow room is usually preferable to a square one. The ceiling height of a boiler room varies from a minimum of 12 ft (3660 mm) for a building of moderate size to a maximum of 16 ft (4880 mm) for a large building.

The size of the chimney that is associated with fuel-burning boilers varies with the type of fuel, the height of the chimney, the type of draft (natural, forced, or induced) that is employed, and other factors. For preliminary design purposes, allow a floor area of 2 ft × 2 ft (610 mm square) for a chimney in a very small building and 6 ft × 6 ft (1830 mm square) in a very large building, interpolating between these extremes for buildings of intermediate size. Keep in mind that the chimney runs through every floor of the building above the boiler room.



**TYPICAL LAYOUT OF A BOILER ROOM**

## CHILLED WATER PLANT

The chilled water plant produces cold water, usually 42° to 45°F (5° to 6°C) in temperature, which is used for cooling the building. The chillers are fueled by electricity, gas, or steam. The chillers give off heat, noise, and vibration, and should not be located near spaces they will adversely affect. They may be placed anywhere in the building from basement to roof, but they are heavy and require deeper-than-normal structural members for support. An outside wall location is desirable to allow for the necessary ventilation and maintenance access. Ideally, the chilled water plant should be adjacent to the boiler room; the two are often housed in the same room in a building of moderate size. Chilled water supply and return pipes run from the chilled water pumps to the fan rooms or terminals that they serve. Condenser water supply and return pipes run between the chillers and the cooling towers.

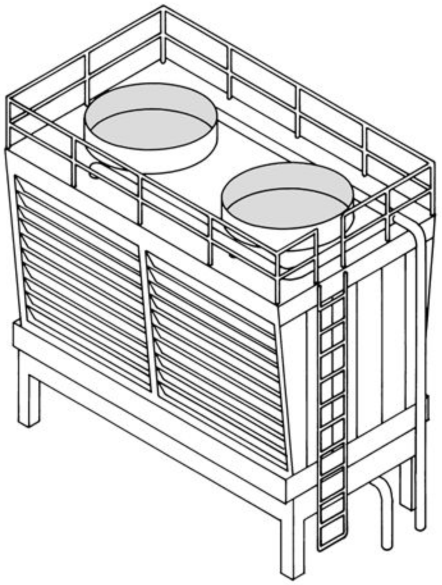
An approximate floor area for a chilled water plant may be determined using the chart on pages 210–211. In larger buildings, a long, narrow room is usually preferable to a square one. The ceiling height of a chilled water plant varies from a minimum of 12 ft (3660 mm) for a building of moderate size to a maximum of 16 ft (4880 mm) for a very large building.

## COOLING TOWERS

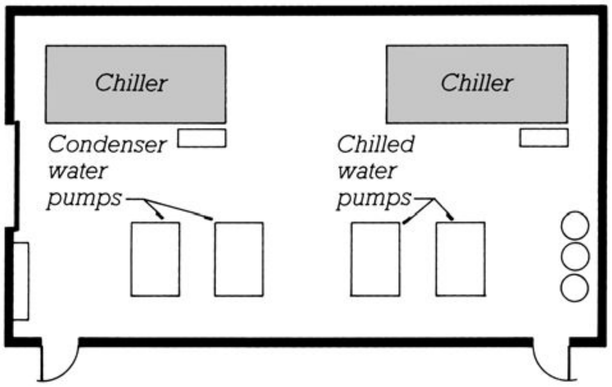
Cooling towers extract heat from the water that is used to cool the condenser coils of the chilled water plant. In effect, the cooling towers are the mechanism by which the heat removed from a building by the air conditioning system is dissipated into the atmosphere. Most cooling towers are "wet," meaning that the hot water from the condensers splashes down through the tower, giving off heat by evaporation and convection to a stream of air that is forced through the tower by fans. The cooled water is collected in a pan at the bottom of the tower and circulated back to the chillers.

The size and number of cooling towers are related to the cooling requirements of the building. Cooling towers may be located on the ground if they are at least 100 ft (30 m) from any building or parking lot to avoid property damage and unhealthful conditions from the splash, fog, and microorganisms given off by the towers. An alternate location is the roof of the building, but because of the noise and vibration they generate, the towers should be isolated acoustically from the frame of the building, and noise-sensitive areas such as auditoriums and meeting rooms should not be located directly below them. Rooftop cooling towers must be located well away from windows and fresh air louvers.

A preliminary estimate of the roof or ground area occupied by cooling towers may be obtained from the chart on pages 210–211. Cooling towers range between 13 and 40 ft (4 and 12 m) in height; the height for a given building can be estimated by interpolating between these two extremes. The towers usually have a 4-ft (1.2-m) crawlspace beneath. For free airflow, they should be located one full width apart and at least 10 to 15 ft (3 to 5 m) from any screen wall or parapet wall unless the wall has very large louvers at the base to allow for intake air.



COOLING TOWER



TYPICAL LAYOUT OF A CHILLED WATER PLANT

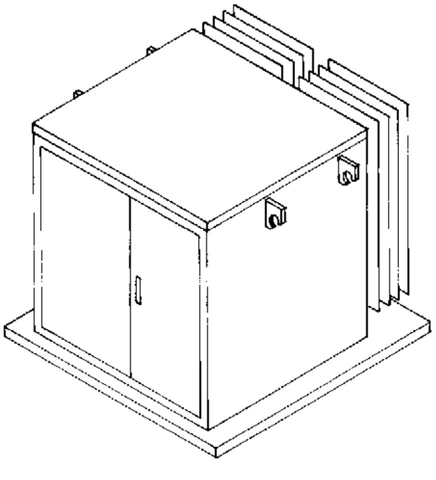
## ELECTRICAL SERVICE ENTRANCE, TRANSFORMERS, SWITCHGEAR, AND EMERGENCY/STANDBY POWER

Every building has an electrical transformer or transformers, a meter or meters, and a panel or switchgear that distributes the power to the interior wiring that services the building. The locations and sizes of these elements vary considerably, depending on the size and purpose of the building, the type of electric service provided by the local utility, the standards and practices of the utility company, the preferences of the building owner, the judgment of the electrical engineer, and local electrical codes.

For reasons of efficiency, electric utilities transmit electricity at high voltages. Transformers reduce this to lower voltages that can be utilized directly in the building—typically 120/208 volts or 115/230 volts in wall and floor receptacles, and up to 480/277 volts in some types of machinery and lighting fixtures. A commercial building of up to 25,000 sq ft (2500 m$^2$) or a residential building of up to twice this size will most often buy its electricity at these lower voltages. For buildings in this size range, the transformer is provided by the utility company and may be mounted overhead on a transmission pole, on the ground (especially where transmission lines are underground), or, in some dense urban situations, in a nearby building or underground vault. A meter or meters belonging to the utility company are installed on or in the building where the service wires enter, and distribution within is usually by means of panels of circuit breakers that are located in an adjacent utility space or a small electrical closet.

Owners of larger buildings sometimes prefer to buy electricity at these lower voltages, but they can obtain energy more economically by providing their own transformers and purchasing electricity at the higher transmission voltage. One typical pattern is to bring electricity to the building at 13,800 volts and then to step down to 480/277 volts with a large primary transformer or transformers at the service entrance. The 277-volt electricity is used directly in many types of commercial and industrial lighting, and at 480 volts, electricity can be distributed efficiently to electrical closets in various parts of the building. Each electrical closet houses one or more small secondary transformers to step down from 480 volts to the lower voltages needed for convenience receptacles and machinery.

Primary transformers may be located either outside or inside the building. Where space is available, an outdoor transformer mounted on a ground-level concrete pad is preferred to an indoor transformer, because it is less expensive, cools better, is easier to service, transmits less noise to the building, and is safer against fire. Some common dimensions of pad-mounted transformers are shown in the upper table on the facing page. A transformer of this type does not need to be fenced except for visual concealment, in which case there must be a clear space of 4 ft (1.2 m) all around the pad for ventilation and servicing. The pad should be within 30 ft (9 m) of a service road and requires a clear service lane 6 ft (1.83 m) wide between the transformer and the road. Multiple outdoor transformers are often used to serve larger buildings and are usually placed at intervals around the perimeter of the building to supply electricity as close as possible to its point of final use.



PAD-MOUNTED TRANSFORMER

In a dense urban setting, or where the building owner finds outdoor placement objectionable, the primary transformer or transformers must be located within the building. Oil-filled transformers of the type the utility company provides for large buildings must be placed in a transformer vault, which is a fire-rated enclosure with two exits. In a few large cities, it is customary to place the transformer vault under the sidewalk, covered with metal gratings for ventilation. Dry-type transformers of the kind usually bought by owners of small and medium-sized buildings do not need a vault; they may be placed in the main electric room. The transformer vault or main electric room is often placed in the basement or on the ground floor but may be located on higher floors. Primary transformers are very heavy and require a heavier, deeper supporting structure than the rest of the building.

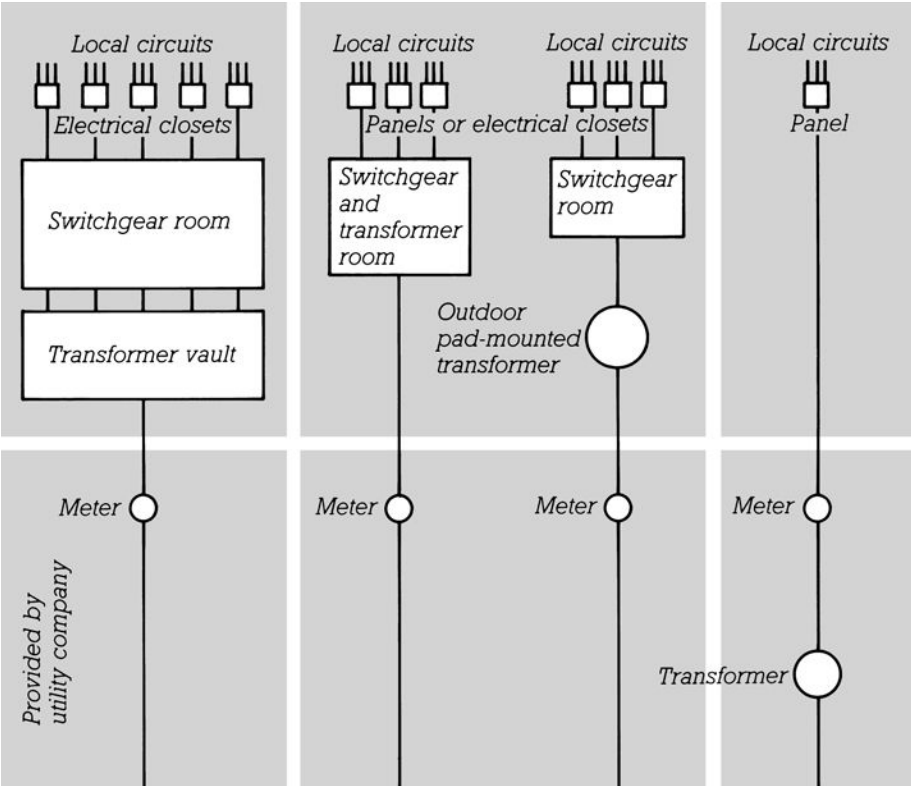
In buildings with dry-type transformers, the switchgear, consisting of disconnect switches, secondary switches, fuses, and circuit breakers, may be housed in the same enclosure with the transformers in a configuration known as a *unit substation*. In large buildings with oil-filled transformers, the switchgear is located in a room adjacent to the transformer vault.

# MAJOR EQUIPMENT SPACES FOR LARGE BUILDINGS

Transformers and switchgear must be ventilated because they give off large quantities of heat. It is best to locate them against an outside wall so that high and low convective ventilation openings can be provided. If this is not possible, ventilation can be accomplished by ductwork and fans connected to outdoor air louvers. Access panels or doors must be provided for servicing and replacing switchgear and transformers. Some examples of sizes of transformer vaults and switchgear rooms are given in the lower table on this page.

Several large conductors run from the transformers to the switchgear and from the switchgear to the vertical and horizontal distribution components that feed electrical closets throughout the building. For information on vertical distribution and electrical closets, see page 193. For information on horizontal distribution, see pages 205–209.

Where it is important to maintain a continuous supply of electrical power, service may be brought to a building from two or more independent electric substations and possibly routed through separate transformers and switchgear at the building site. In this way, the building is less vulnerable to power outages resulting from a single point of failure in the upstream supply.



**LARGE BUILDINGS** **MEDIUM-SIZED BUILDINGS: TWO ALTERNATIVES** **SMALL BUILDINGS**

**TYPICAL DIMENSIONS OF PAD-MOUNTED TRANSFORMERS**

| Floor Area of Commercial Building | Number of Residential Units | Pad Size |
|---|---|---|
| 18,000 ft$^2$ (1,700 m$^2$) | 50 | 52 × 44 in. (1.3 × 1.2 m) |
| 60,000 ft$^2$ (5,700 m$^2$) | 160 | 52 × 50 in. (1.3 × 1.3 m) |
| 180,000 ft$^2$ (17,000 m$^2$) | — | 96 × 96 in. (2.4 × 2.4 m) |

**TYPICAL SIZES OF TRANSFORMER VAULTS AND SWITCHGEAR ROOMS**

| Floor Area of Commercial Building | Floor Area of Residential Building | Size of Combined Room for Transformers and Switchgear | Size of Transformer Vault | Size of Switchgear Room |
|---|---|---|---|---|
| 150,000 ft$^2$ (15,000 m$^2$) | 300,000 ft$^2$ (30,000 m$^2$) | 30 × 30 × 11 ft (9.14 × 9.14 × 2.44 m) | | |
| 100,000 ft$^2$ (10,000 m$^2$) | 200,000 ft$^2$ (20,000 m$^2$) | | 20 × 20 × 11 ft (6.0 × 6.0 × 3.35 m) | 30 × 20 × 11 ft (9.0 × 6.0 × 3.35 m) |
| 300,000 ft$^2$ (30,000 m$^2$) | 600,000 ft$^2$ (60,000 m$^2$) | | 20 × 40 × 11 ft (6.0 × 12.0 × 3.35 m) | 30 × 40 × 11 ft (9.0 × 12.0 × 3.35 m) |
| 1,000,000 ft$^2$ (100,000 m$^2$) | 2,000,000 ft$^2$ (200,000 m$^2$) | | 20 × 80 × 11 ft (6.0 × 24.0 × 3.35 m) | 30 × 80 × 11 ft (9.0 × 24.0 × 3.35 m) |

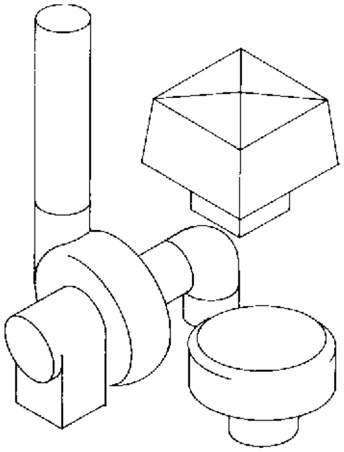
# MAJOR EQUIPMENT SPACES FOR LARGE BUILDINGS

In many buildings, on-site equipment capable of generating power in the event of an interruption in normal electrical service is also required. Such equipment can provide *emergency power* for building systems essential to life safety—such as assembly area lighting, fire detection, alarm systems, fire pumps, elevators, and emergency communications—or *standby power* for less essential services. The equipment consists of one or more electrical generators driven by engines fueled with natural gas, propane gas, diesel oil, or gasoline. In the case of all but natural gas, on-site fuel storage is also required. During testing and operation, large quantities of air for combustion and cooling are required, and exhaust gases, noise, and vibration are emitted. The best location for power generating equipment is on the ground outside the building, near the switchgear room. Engine-generator sets in prefabricated weather-resistant housings are available for this purpose. The next best location is on the roof of the building. Alternatively, this equipment may be located inside the building on an exterior wall, as far as possible from occupied areas of the building and within a fire-resistance rated enclosure. Typical dimensions for the housing or room to accommodate an emergency power supply for an average commercial building of up to 150,000 sq ft (14,000 m$^2$) are 12 ft (3.7 m) wide and 18 ft (5.5 m) long. A space of the same width, 22-ft (6.7-m) in length, will accommodate the supply for a building of up to 400,000 sq ft (37,000 m$^2$). Where additional standby power is required, space requirements will be greater.

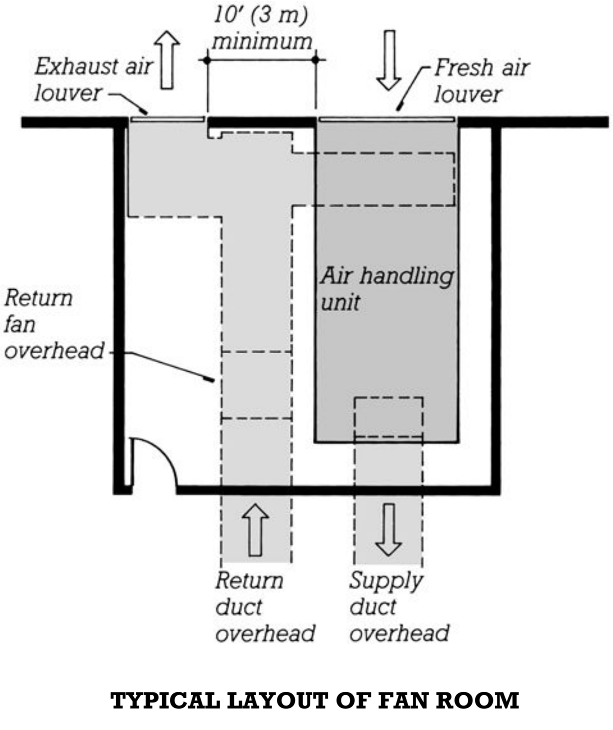
There is a loss of power for a period of up to 10 seconds between the time a power interruption occurs and the time an on-site generator takes over. Where this brief interruption is unacceptable, such as in buildings with specialized medical equipment, computers, communications equipment, certain types of lighting, or an extraordinary need for security, a battery-powered uninterruptible power supply (UPS) provides electricity during this transition. The UPS requires a room for batteries and an adjacent room for specialized circuit breakers and electronic controls. These should be located close to the area that utilizes the UPS power. A typical computer room of 10,000 sq ft (1000 m$^2$) requires an outside-ventilated battery room of 500 sq ft (47 m$^2$) and a room of 200 sq ft (19 m$^2$) for electronic equipment. Both of these rooms require air conditioning. Depending on the power capacity, the enclosure of the UPS equipment may be required to be fire-resistance rated.

## EXHAUST FANS

Exhaust fans draw air constantly from toilet rooms, locker rooms, bathrooms, janitor closets, storage rooms, corridors, and kitchens and deliver it to the outdoors to keep the air fresh in these spaces. Exhaust fans are also used to evacuate air from laboratory fume hoods and many industrial processes. The fans are usually housed in small mushroom ventilators on the roof and are connected to the spaces they serve by ducts that run through the vertical shafts in the cores of the building. It is difficult to generalize about the sizes of exhaust ducts and fans; they tend not to be extremely large, so it is usually sufficient to allow a small amount of shaft space and roof space that can later be adjusted in consultation with the mechanical engineer.



**EXHAUST FANS**



**TYPICAL LAYOUT OF FAN ROOM**

# MAJOR EQUIPMENT SPACES FOR LARGE BUILDINGS

## FAN ROOMS AND OUTDOOR AIR LOUVERS

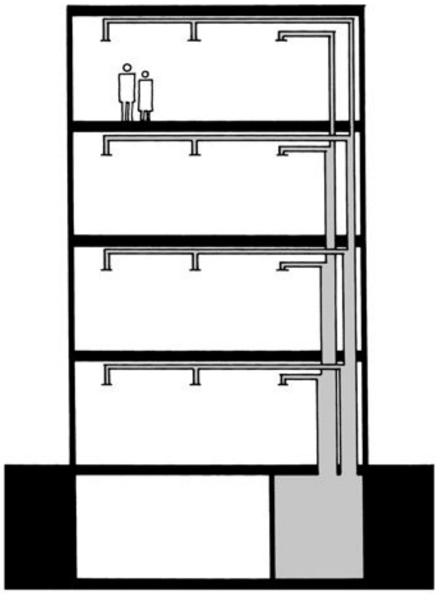
In an all-air system, an air handling unit in a fan room circulates air through a filter and hot water and chilled water coils to condition it. The conditioned air is ducted to the occupied spaces of the building. A return fan draws air from the occupied spaces into return grilles and back to the fan room through return ducts. Just before it passes through the heating and cooling coils again, a portion of the air is diverted by a damper and exhausted through a louver to the outdoors. An equal portion of fresh air is drawn in through another outdoor louver and added to the stream of return air.

Fan rooms may be located anywhere in the building; they are supplied with hot and chilled water through insulated pipes from the boiler room and the chilled water plant. A floor plan of a typical fan room is shown on the facing page. If only a single fan room is used, it may be placed in the basement, on the ground floor, on the roof, or on any intermediate floor, as close to the vertical distribution shafts as possible. It is most convenient to locate this room near an outside wall, but if an outside wall location is not possible, ducts to the outdoors are used to convey fresh air and exhaust air to and from the fan. These ducts may run horizontally, above a ceiling, or vertically, in a shaft.

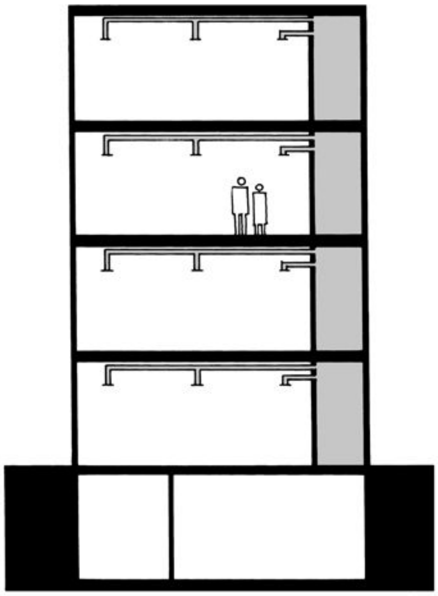
The maximum vertical "reach" of a fan room is approximately 25 stories up and/or down; more typically, fan rooms are located so that none of them needs to circulate air more than 11 to 13 stories in each direction.

Multiple fans distributed throughout the building are often desirable because they allow the building to be zoned for better local control, and they reduce the total volume of ductwork in the building. It can be advantageous to have a separate fan room for each floor of a building, because this saves floor space by eliminating most or all of the vertical runs of ductwork. Separate fan rooms are used in buildings that bill tenants individually for heating and cooling costs.

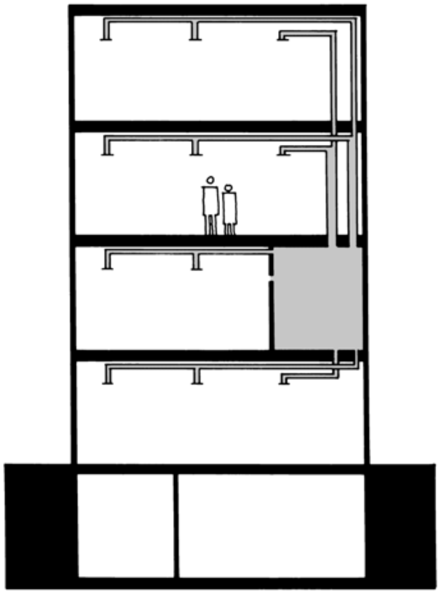
Fan room equipment is often heavy enough to require stronger structural support than the surrounding areas of the building. Noise-sensitive areas such as meeting rooms and auditoriums should not be located adjacent to fan rooms, which produce vibration and noise.



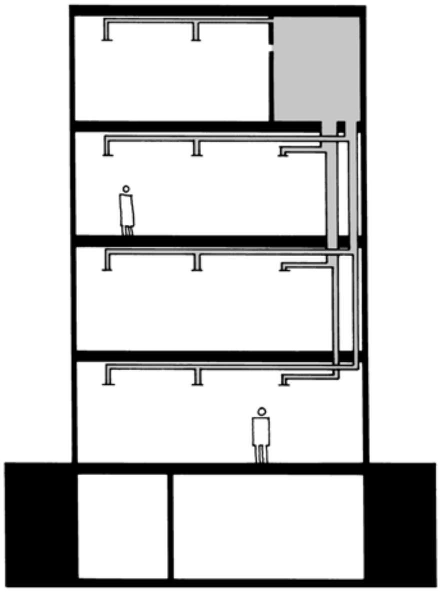
FAN ROOM IN A BASEMENT



FAN ROOM ON EACH FLOOR



FAN ROOM ON AN INTERMEDIATE FLOOR



FAN ROOM AT THE TOP OF A BUILDING

The fresh air and exhaust air louvers associated with a fan room are noisy and create strong local air currents. They need to be located a short distance apart, usually at least 10 ft (3 m), on the exterior wall, so that the outgoing and incoming air do not mix. Louvers for small pieces of equipment such as fan-coil units are very small. With careful design work, they can be integrated unobtrusively into the fabric of the wall. Louvers for larger pieces of equipment grow progressively larger with the floor area each serves. They are large and conspicuous for central fans serving a number of floors and require special attention on the part of the architect.

Use the graph on pages 212–213 to determine the approximate sizes of outdoor louvers for preliminary design purposes. The same graph gives information on sizing fan rooms as a function of floor area served. Using this graph, one may quickly evaluate a number of schemes for air distribution, using one fan room or many, to determine the effect of each scheme on the space planning and the exterior appearance of the building.

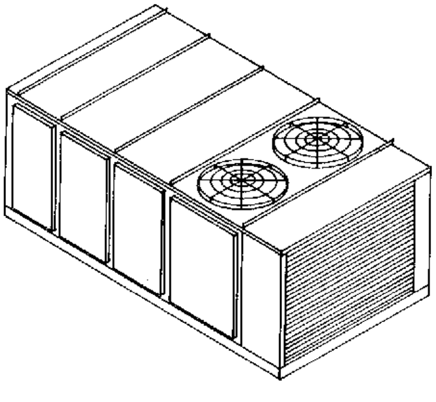
## LOADING DOCK AND ASSOCIATED SPACES

Every large building needs at least a single loading dock and freight room for receiving and sending mail and major shipments, moving tenant furniture in and out, removing rubbish, and facilitating the servicing of mechanical and electrical equipment. The dock needs to be situated so that trucks may back up to it easily without obstructing traffic on the street. The freight room inside the dock area should open directly to the rubbish compactor and the freight elevators, and should be connected to the major mechanical equipment spaces and the mailroom. It is often appropriate to locate the oil filler pipes next to the truck ramp that leads to the loading dock. If possible, the access doors to the major equipment spaces should also open to the dock or ramp area.

## PACKAGED CENTRAL HEATING AND COOLING EQUIPMENT

Packaged central heating and cooling equipment comes in two different configurations:

- *Single-packaged* heating and cooling equipment combines the functions of a boiler room and chimney, a chilled water plant, and a fan room into a compact, rectangular, weatherproof unit that is specified, purchased, and installed as a single piece of equipment. The supply and return ducts from the building are connected through the roof or the wall of the building to the fan inside the packaged unit.
- *Split-packaged* units are furnished in two parts: an outdoor package that incorporates the compressor and condensing coils, and an indoor package that contains the cooling and heating coils and the circulating fan. The two packages are connected by insulated refrigerant tubing and control wiring. Split-packaged units cost slightly more than single-packaged units, but they are slightly more energy efficient because none of their ductwork is located outside the insulated shell of the building.



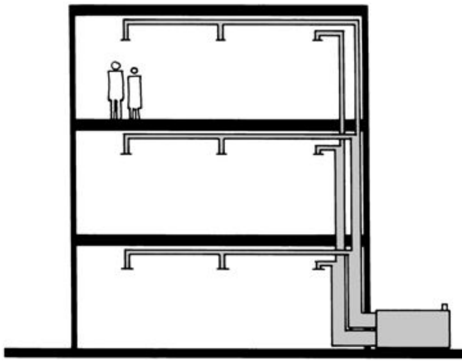
**SPLIT-PACKAGED UNIT**

Packaged units, whether single or split, are fueled entirely by electricity or by a combination of electricity and gas. Packaged equipment is simple for the designer to select and specify, and is easy to purchase and install, because it is supplied as off-the-shelf units that need only external connections to fuel, electricity, control wiring, and air ducts.

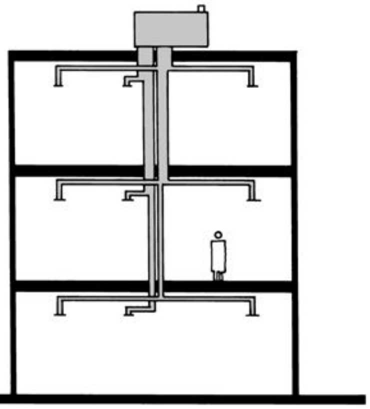
Packaged units are available in single-zone and multizone configurations in a variety of sizes to serve a wide range of demands for cooling and heating. They can be purchased as variable air volume or constant air volume (VAV or CAV) systems (see pages 168–171).

Single-packaged units are generally located either on the roof or on a concrete pad alongside the building. If alongside, the supply and return ducts are connected to the end of the unit and pass through the side wall of the building before branching out to the spaces inside. In a rooftop installation, the ducts pass through the bottom of the unit and into the building. The ducts from single-packaged units can serve low multistory buildings through vertical shafts that connect to above-ceiling branch ducts on each floor. Rooftop units may be placed at intervals to serve a building of any horizontal extent. The same is true of units located alongside the building, although the depth of the building is somewhat restricted by the maximum practical reach of the ducts. Using the chart on pages 212–213, you may select a combination of unit size and numbers of units to serve any desired size and shape of building. For buildings taller than four or five stories, or for large buildings where only one central plant may be installed, conventional central equipment assembled from components must be used because of the relatively limited capacity range of packaged units.

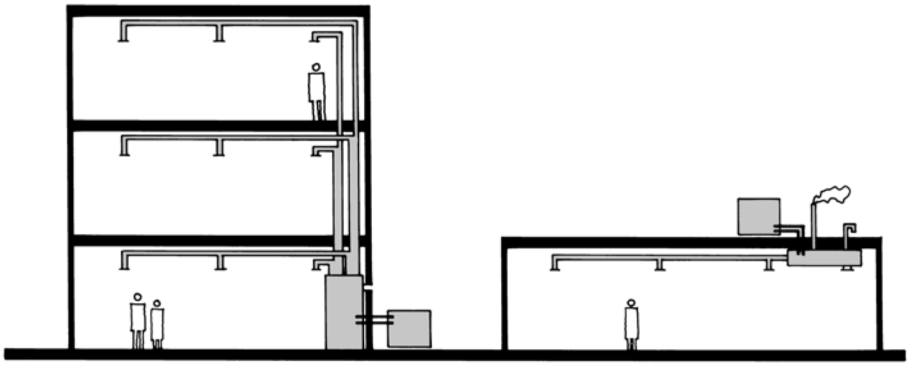
The table below will help to determine preliminary sizes for split-packaged equipment. The inside package may be obtained as a horizontal unit that hangs from the roof structure or as a vertical unit that stands on the floor. The outside package may be located on the roof or on a concrete pad next to the building.



**THROUGH-THE-WALL SINGLE-PACKAGED UNIT**



**ROOFTOP SINGLE-PACKAGED UNIT**



**SPLIT-PACKAGED UNITS**

**TYPICAL DIMENSIONS OF SPLIT-PACKAGED COMPONENTS**

| **Cooling Capacity in Tons (mcal/sec)** | | **10 (35)** | **20 (70)** | **30 (106)** | **40 (141)** | **50 (176)** |
|---|---|---|---|---|---|---|
| **Outdoor Unit** | Length | 6'–4"<br>(1.93 m) | 12'–11"<br>(3.94 m) | 12'–11"<br>(3.94 m) | 12'–11"<br>(3.94 m) | 12'–11"<br>(3.94 m) |
| | Width | 3'–8"<br>(1.12 m) | 4'–0"<br>(1.22 m) | 4'–10"<br>(1.47 m) | 7'–1"<br>(2.16 m) | 7'–1"<br>(2.16 m) |
| | Height | 3'–4"<br>(1.02 m) | 2'–4"<br>(0.71 m) | 3'–2"<br>(0.97 m) | 4'–9"<br>(1.45 m) | 5'–8"<br>(1.73 m) |
| **Indoor Ceiling-Suspended Unit** | Length | 8'–3"<br>(2.51 m) | 7'–10"<br>(2.39 m) | 9'–0"<br>(2.74 m) | 9'–8"<br>(2.95 m) | 9'–8"<br>(2.95 m) |
| | Width | 5'–3"<br>(1.60 m) | 6'–8"<br>(2.03 m) | 7'–10"<br>(2.39 m) | 10'–7"<br>(3.23 m) | 10'–7"<br>(3.23 m) |
| | Height | 2'–2"<br>(0.66 m) | 2'–6"<br>(0.76") | 3'–0"<br>(0.91") | 3'–10"<br>(1.17 m) | 3'–10"<br>(1.17 m) |
| **Indoor Floor-Mounted Unit** | Length | 5'–3"<br>(1.60 m) | 6'–8"<br>(2.03 m) | 7'–10"<br>(2.39 m) | 10'–7"<br>(3.23 m) | 10'–7"<br>(3.23 m) |
| | Width | 2'–2"<br>(0.66 m) | 2'–6"<br>(0.76 m) | 3'–0"<br>(0.91 m) | 3'–10"<br>(1.17 m) | 3'–10"<br>(1.17 m) |
| | Height | 8'–3"<br>(2.51 m) | 7'–10"<br>(2.39 m) | 9'–0"<br>(2.74 m) | 9'–8"<br>(2.95 m) | 9'-8"<br>(2.95 m) |

Use the chart on pages 210–211 to estimate the required cooling capacity.

## SEWAGE EJECTOR PIT

If the lowest level of a building lies below the level of the sewer or septic tank, sewage is collected in an underfloor pit and pumped up to the sewer. The pumps do not necessarily occupy floor space, because they are usually contained within the pit, but the pit must lie beneath unobstructed floor space so that it can be inspected and serviced through a removable cover.

## TELECOMMUNICATIONS ROOM

A central room for telephone and data systems should be located in the basement or on the ground floor as close to the telecommunications service entrance as possible. Where telecommunications distribution closets are stacked on floors above, this room should be located directly below these closets as well. Equipment needs in this room will vary, depending on the particular systems to be installed, and are also likely to vary significantly over time. For this reason, this room, and all other components of the telecommunications distribution system in the building, should be configured with ease of access and maximum flexibility in mind. For preliminary design purposes, the service entrance room should be no smaller than 60 sq ft (6 $m^2$), and may be 400 sq ft (40 $m^2$) in size or larger for a large commercial office building. The room should be free of plumbing, steam, or other piping and should be in a separate cooling zone to allow independent temperature control. From this room, telecommunications wiring extends to distribution closets on each floor (see page 193).

## WASTE COMPACTOR

A waste compactor is necessary in most large buildings. It may be coupled with a container system to facilitate the trucking of the compacted rubbish.

The compactor is often served by a vertical refuse chute from the upper floors of the building. The chute must be placed in a fire-resistance rated enclosure and must be provided with an automatic sprinkler head above the top opening. Some codes also require the provision of a fire-resistance rated enclosed chute room outside the chute opening at each floor. Inside diameters of chutes range from 15 to 30 in. (380 to 760 mm), with 24 in. (610 mm) being a typical dimension.

The waste compactor should be located directly beneath the refuse chute and adjacent to the loading dock. The size and shape of the compactor itself vary widely with the manufacturer and the capacity of the unit. A compactor room of 60 sq ft (5.6 m$^2$) is sufficient for a small apartment building. A larger building will require 150 to 200 sq ft (14.0 to 18.6 m$^2$), and industrial waste compacting facilities can be much larger.

## WATER PUMPS

Where the water service enters the building, a room is required to house the water meter and the sprinkler and standpipe valves. In a building taller than three or four stories, a suction tank and a pair of water pumps are needed to boost the water pressure in the domestic water system. A similar pair of pumps is required for all but very small sprinkler systems. A chiller for drinking water and a heat exchanger to heat domestic hot water are often located in the same area. The table below will assist in determining the necessary floor areas for water pumps. The enclosures for fire pump rooms in high-rise buildings are often required to be fire-resistance rated.

In a few large cities, local codes require the provision of a large gravity tank on the roof of the building to furnish a reserve of water in case of fire. In most areas, however, the pumps alone are sufficient.

## WORKROOMS, CONTROL ROOMS, AND OFFICES

Operating and maintenance personnel in large buildings need space in which to work. Offices should be provided for operating engineers and maintenance supervisors. A room is required to house the control console for a large-building heating and cooling system. Lockers and workrooms are needed for mechanics, plumbers, electricians, and custodial workers. Storage facilities should be provided near the loading dock and service elevator for tools, spare parts, and custodial equipment and supplies.

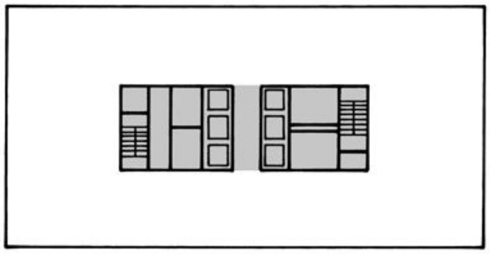
### SPACE REQUIREMENTS FOR WATER PUMPS

**Domestic Water Pumps**

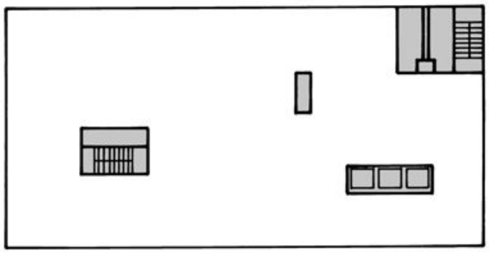
| Area Served | Room Dimensions |
|---|---|
| Up to 200,000 ft$^2$<br>(Up to 18,600 m$^2$) | 8' × 12'<br>(2.44 × 3.66 m) |
| 200,000 to 1,000,000 ft$^2$<br>(18,600 to 93,000 m$^2$) | 16' × 12'<br>(4.88 × 3.66 m) |

**Fire Pumps (assuming sprinklers)**

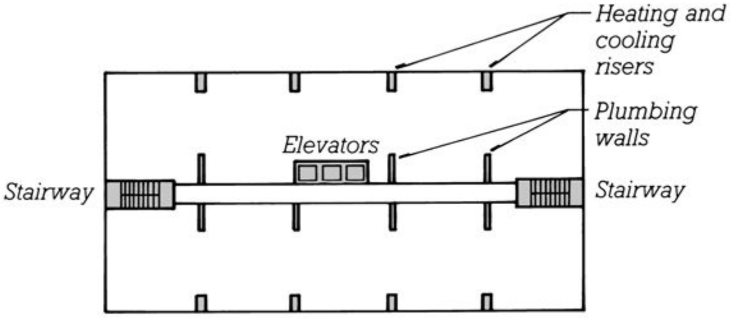
| Area Served | Room Dimensions |
|---|---|
| Up to 100,000 ft$^2$<br>(Up to 9300 m$^2$) | 8' × 12'<br>(2.44 × 3.66 m) |
| 100,000 to 200,000 ft$^2$<br>(9300 to 18,600 m$^2$) | 20' × 12'<br>(6.1 × 3.66 m) |
| 1,000,000 ft$^2$<br>(93,000 m$^2$) | 30' × 24'<br>(9.15 × 7.32 m) |



HIGH-RISE OFFICE BUILDING: VERTICAL SERVICES IN A CONCENTRATED CORE



LOW-RISE BUILDING: VERTICAL SERVICES IN SCATTERED LOCATIONS



HOTEL OR APARTMENT BUILDING: VERTICAL SERVICES BETWEEN UNITS

## PLANNING SERVICE CORES

Spaces for the vertical distribution of mechanical and electrical services in a large building need to be planned simultaneously with other building elements that are vertically continuous or that occur in stacks—principally the structural columns, bearing walls, shear walls, and wind bracing; exit stairways; elevators and elevator lobbies; and rooms with plumbing: toilet rooms, bathrooms, kitchens, and janitor closets. These elements tend to coalesce into one or more core areas where the vertically continuous elements are concentrated into efficient, packaged blocks of floor space, leaving most of each floor open for maximum flexibility of layout.

Different types of buildings call for different sorts of core arrangements. In high-rise office buildings, where a maximum amount of unobstructed, rentable area is the major criterion for floor layout, a single central core is almost universal. In low-rise commercial and institutional buildings, horizontal distances are often great enough that a single core would be inefficient, and vertical elements are divided into several cores of varied internal composition. These are likely to be located asymmetrically in response to the servicing and circulation patterns of the building. In a dormitory, apartment building, or hotel, a common pattern of vertical services features slender shafts sandwiched between the living/sleeping units. Shafts next to the interior corridor carry the plumbing for the bathrooms and kitchens that back up to them. If the heating and cooling equipment for the units is located over the bathrooms and kitchens, the hot and chilled water piping and ductwork may share these same shafts. If the heating and cooling are done along the outside walls, another set of shafts may be created between units around the perimeter of the building to serve this equipment.

Vertical distribution shafts need to connect directly with the major equipment spaces that feed them and the horizontal distribution lines they serve. The boiler room, chilled water plant, central fan room, exhaust fans, water pumps, sewage ejector, waste compactor, and cooling towers need to cluster closely around the vertical distribution shafts. The electric and telecommunications switchgear should not be far away. The electrical and telecommunications closets must stack up along the wiring shafts at each floor. The toilet rooms, bathrooms, kitchens, and janitor closets must back up to plumbing walls. Horizontal supply and return ducts need to join easily with the vertical ducts in the shafts, and horizontal piping for hot and chilled water distribution must branch off conveniently from the riser pipes.

To protect against the rapid spread of smoke and fire between building floors, the enclosing walls of shafts of all types, including those for stairs, elevators, and building services, must almost always be fire-resistance rated—see pages 376–379 for more information.

## LOCATING THE CORES IN THE BUILDING

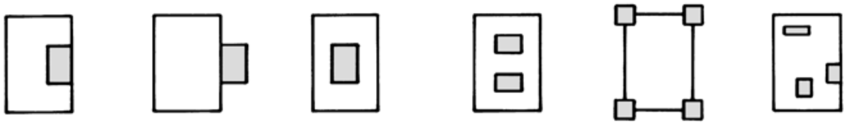
A centrally located core leaves the daylit perimeter area of the building open for occupant use. It also works efficiently with a scheme that distributes services horizontally from one set of shafts, because it minimizes duct and pipe sizes. The central location can be undesirable, however, because it interrupts the open space of the floor. A core at one edge of the building does not have this problem, but it may not be able to incorporate exit stairways that are separated widely enough (see page 267), and it obstructs a portion of the daylit perimeter. Either of these core locations connects well to major equipment on the ground, the roof, and any intermediate mechanical floors.

A core located in a corner, on the other hand, is undesirable because horizontal distribution lines from the core are long, exit stairways are too close together, and connections to major equipment are congested. Two or more corner cores used in combination can overcome some of these problems.

Multiple cores often work well, particularly in broad, low-rise buildings. Exit stairways can be widely separated and connected to a simple, clear system of corridors and elevators. Vertical risers for mechanical services can be located where they work best, minimizing the congestion of ducts and pipes at points of connection to horizontal networks.

Core locations may also be dictated in part by the structural scheme that provides lateral stability to the building. A large, centrally located core or two symmetrically placed cores can furnish ideal locations for wind and seismic bracing. A core at the edge of the building or a detached core cannot house all the bracing for the building because it is located asymmetrically with respect to one of the principal axes of the building (see pages 39–41). Scattered cores and corner cores may not be large enough to develop the required depth of bracing elements.

The chart below summarizes some of the advantages and disadvantages of different options for core placement.



**CHARACTERISTICS OF CORE PLACEMENTS**

| 1 = Best 5= Worst | Edge | Detached | Central | Two | Corners | Scattered |
|---|---|---|---|---|---|---|
| Flexibility of typical rental areas | 2 | 1 | 3 | 4 | 2 | 5 |
| Perimeter for rental areas | 4 | 3 | 1 | 1 | 5 | 2 |
| Ground floor high-rent area | 3 | 1 | 3 | 4 | 2 | 5 |
| Typical distance of travel from core | 4 | 5 | 2 | 1 | 3 | 3 |
| Clarity of circulation | 3 | 4 | 2 | 1 | 3 | 5 |
| Daylight and view for core spaces | 2 | 1 | 5 | 5 | 1 | 4 |
| Service connections at roof | 3 | 4 | 2 | 1 | 5 | 3 |
| Service connections at ground | 3 | 4 | 2 | 1 | 5 | 3 |
| Suitability for lateral bracing | 4 | 5 | 1 | 1 | 2 | 3 |

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## PLANNING THE INTERNAL ARRANGEMENT OF THE CORES

The ratio of the total floor area of the core or cores of a building to the floor area served varies widely from one building to the next. The average total area of the cores in 40- to 70-story New York City office buildings, including the stairways, toilets, elevators, and elevator lobbies, is approximately 27% of the open area of each floor served by the core. This percentage runs as high as 38% in some older buildings but is around 20% to 24% in office towers of recent design. At the other extreme, the total core area of a three-story suburban office building is likely to be about 7% of the floor area served, because there are few elevators, much less lobby space for elevators, and much smaller shafts for mechanical and electrical services.

These percentages also vary with the relative requirements for mechanical and electrical services; they can be higher in a hospital or laboratory and are much lower in a hotel or apartment building. Core area is directly related to the type of heating and cooling system used: The percentages quoted in the preceding paragraph apply to buildings with all-air systems. Buildings with air-and-water and all-water systems require somewhat less shaft space.

A building with a fan room on each floor will need very little core area for ductwork, but the fan room is likely to occupy at least as much floor space as the vertical ductwork it eliminates.

The structural scheme of a building can also have a direct effect on the core area. Of the total core area of a tall office building, about 12% is usually occupied by columns, bracing, walls, and partitions. This percentage is lower for lower buildings and can be very low in buildings whose core areas contain no columns or lateral bracing.

The most critical elements of the core, those that should be located first in at least a tentative way, are the columns and lateral bracing, the exit stairways, and the elevators and elevator lobbies. Next should come the plumbing walls and the shafts for ductwork. For help in laying out the structural elements, see pages 39–53. Details of the location and configuration of exit stairways are given on pages 267–268 and 272–275. Pages 201–203 give advice on the number, size, and layout of elevator shafts and lobbies. Plumbing walls are illustrated on page 195, and ductwork shafts can be sized using the chart on pages 212–213.

The chimney is another element for which there may be little flexibility of location. Usually the chimney exits from a corner of the boiler room. It may be sloped at an angle not less than 60° to the horizontal to bring it to a more convenient position in the core. For help in sizing chimneys, refer to page 180.

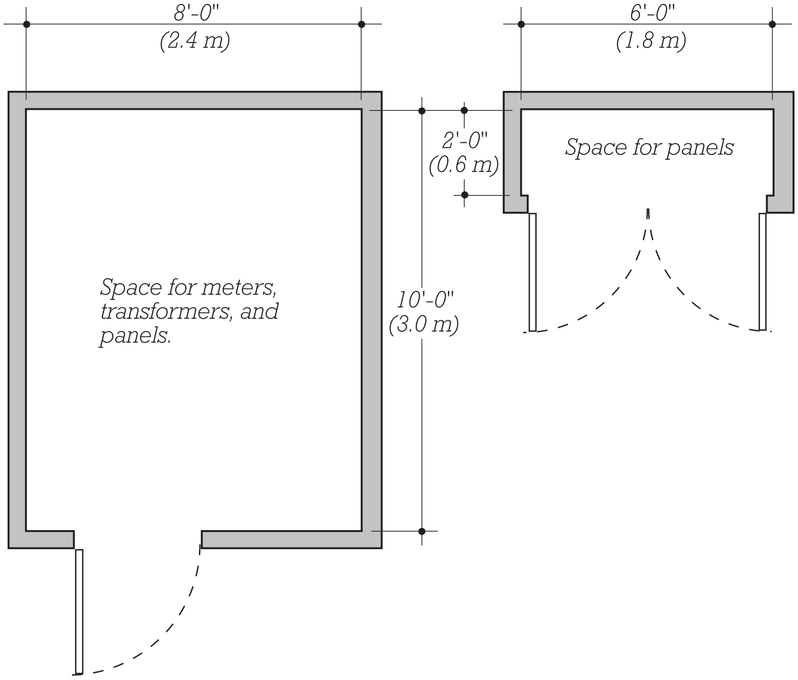
## TOTAL SHAFT AREA

The total open area of all the mechanical and electrical shafts in a tall office building is normally equal to about 4% of the area served on each floor and can be estimated at about half this amount for a low-rise building. This area should be divided into at least two separate shafts to relieve the congestion that would otherwise occur where the vertical and horizontal distribution networks connect. It is especially effective to provide separate shafts for supply and return ducts because it is often possible to use a separate return shaft as a plenum, a shaft that is itself the duct. For maximum utility, the horizontal ratios of each shaft should lie in the range of 1:2 to 1:4. To allow sufficient space for connections to horizontal distribution networks at each floor, no shaft should adjoin stair towers or elevator shafts on more than one long side and one short side.

## ELECTRICAL AND TELECOMMUNICATIONS CLOSETS

Electrical and telecommunications closets must be accessible from public areas of the floor, stacked above one another, and kept free of plumbing, steam, and other types of piping. Typical sizes and configurations for electrical closets are illustrated in the accompanying diagrams. In an office building, major electrical closets should be provided for each 15,000–20,000 sq ft (1400–1900 m$^2$) of floor area so that no point on a floor lies more than 100–125 ft (30–40 m) from the closest closet. If this is difficult to arrange, satellite closets served by cables from the major closets may be used to supply electricity to the more distant areas. In smaller buildings or buildings with lesser power requirements, satellite-size closets may serve in place of major ones. Electrical closets do not normally require fire-resistance rated enclosures, unless they contain large transformers.

The electrical risers that connect stacked closets may either pass between closets through penetrations protected against fire passage in the closet floors or, in taller buildings, travel within dedicated, vertical shafts abutting one wall of the closets. In very tall buildings, such shafts may become so large that they must be configured as complete rooms with their own entrances.



**MAJOR ELECTRICAL CLOSET**

**SMALL OR SATELLITE CLOSET**

Telecommunications closets should be provided for every floor so that no point on the floor is more than 300 ft (90 m) from the closest closet. For commercial office space, telecommunications closets should measure 10 × 12 ft (3.0 × 3.7 m) internally. For less data-intensive occupancies, closets as small as 4 × 5 ft (1.2 × 1.5 m) may be sufficient.

For larger electrical and telecommunications closets, separate cooling should be provided to permit independent temperature control. Doors to these closets should open outward.

## FAN ROOMS

When local fan rooms' fresh air and exhaust air connections are provided by means of duct risers, these rooms should be placed against the shafts containing those ducts. If local fan rooms exchange air directly with the outdoors on each floor, they should be placed against outside walls, or if this is not possible, they can be connected to fresh air and exhaust louvers by horizontal ducts. Heated and chilled water must also be provided to the fan rooms, either via horizontal piping running from the building core or via vertical piping in an immediately adjacent shaft. Fan rooms should be stacked one above the other from floor to floor. See pages 184–186 and 212–213 for information on planning fan rooms.

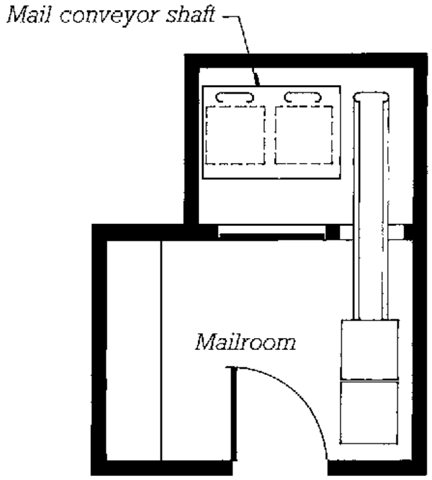
## MAIL FACILITIES

Vertical gravity chutes for mail deposit are often provided in multistory buildings. The chute occupies an area of about 5 × 15 in. (125 × 375 mm) in plan and terminates in a receiving box in the base of the building.

Vertical mail conveyors are sometimes provided for delivery of mail in a large multistory office building. The mailroom at the base of the conveyor should be adjacent to the loading dock and can be sized at about $\frac{2}{10}$ of 1% of the area it serves. The walls around the conveyor shaft itself will vary in plan from 4 ft × 4 ft 6 in. (1220 × 1370 mm) to 7 ft 3 in. × 8 ft 6 in. (2210 × 2590 mm) inside dimensions, depending on the system's capacity and manufacturer. The conveyor should discharge into a service mailroom of at least 6 × 7 ft (1830 × 2135 mm) on each floor. A 1- or 2-hour fire enclosure is required around the conveyor shaft.

## PIPE RISERS FOR HEATING AND COOLING

The insulated pipes that conduct heated and chilled water to and from the spaces in a building require considerable space. In a tall apartment building or hotel, a clear shaft of 12 × 48 in. (300 × 1200 mm) is generally sufficient to serve two stacks of units. This may be sandwiched between units at the perimeter of the building or located adjacent to the central corridor, depending on where the heating and cooling equipment is located in the units.

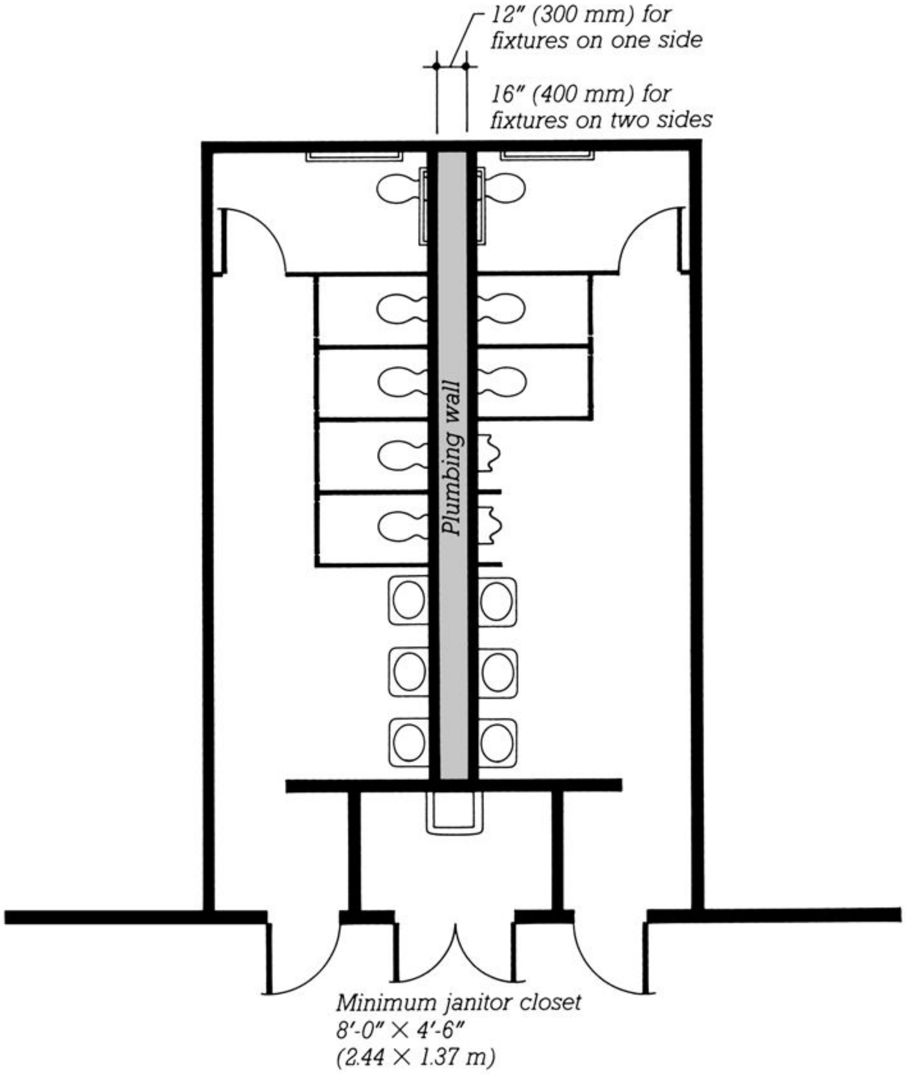


**MAILROOM**

## PLUMBING WALLS, JANITOR CLOSETS, TOILET ROOMS, AND BATHING ROOMS

Fixtures in bathrooms, toilet rooms, shower rooms, kitchens, laundries, and other areas with plumbing should back up to plumbing walls. A plumbing wall has an internal cavity large enough to house the supply, waste, and vent piping necessary to serve the fixtures. Plumbing walls should be stacked vertically from the bottom of the building to the top. It is possible to offset plumbing walls a few feet from one floor to the next, but horizontal offsets are expensive and cause maintenance headaches. A typical plumbing wall arrangement, complete with janitor closet, is illustrated and dimensioned on the diagram to the right. The indicated internal widths of the plumbing wall are adequate for floor-mounted fixtures. If wall-hung fixtures are used, a 24-in. (600-mm) dimension is needed to accommodate the fixture carriers within the wall.

Fixture requirements for toilet rooms are established by plumbing codes. Requirements for the model codes included in this book are reproduced on the following pages. Where building use may change over time, consider providing adequate fixture counts for future uses, as it is costly and time-consuming to add plumbing facilities to existing facilities.



TOILET ROOM AND JANITOR CLOSET

## Minimum Plumbing Fixture Requirements in the International Building Code

Consult the table on the facing page to determine the minimum number of toilet fixtures, lavatories, drinking fountains, and showers required by the International Building Code, based on the Occupancy classification and number of occupants served. See pages 6–12 for more information on determining the Occupancy classifications for your building and page 297 for determining the occupant load. For occupancy types not listed in the table, select the most comparable classification in terms of patterns of use and occupant density.

When determining fixture requirements, the following should also be considered:

- Fixture requirements should be based on the assumption of equal numbers of male and female occupants.
- Under most circumstances, separate toilet facilities are required for each sex. Separate facilities are not required for dwelling units and sleeping units, buildings or tenant spaces with a total occupant load of 15 or less, and Mercantile Occupancies with an occupant load of 50 or less.
- For male toilet facilities, urinals may be substituted for not more than two-thirds of the required water closets.
- Drinking fountains are not required in spaces with an occupant load of 15 or less.
- Toilet facilities for public and employee use must be located within one story above or below and within a 500-ft (152-m) travel distance of the space served. Facilities may in most cases be shared between employees and the public.
- In covered malls, toilet facilities may be located within individual stores or centrally located. The travel distance to public facilities may not exceed 300 ft (91 m) measured from the main entrance to any store or tenant space.
- In Institutional I-2 and I-3 Occupancies, employee and visitor toilet facilities must be separate from resident facilities.
- In Residential R-2 Occupancies, each dwelling unit must be provided with a kitchen sink. At least one automatic clothes washer connection is required for every 20 dwelling units.
- At least one service sink for maintenance personnel should be provided per floor or use area.
- Required toilet room facilities must be free of charge.

## Accessible Plumbing Facilities in the International Building Code

With few exceptions, all toilet and bath facilities within accessible buildings must be made accessible. In all cases, accessible buildings must provide at least one set of accessible facilities. Fully accessible toilet facilities are not required for single-occupant private offices, nonaccessible dwelling or sleeping units, facilities on nonaccessible floors, or facilities for intensive or critical care sleeping rooms.

Accessible toilet facilities must be located on accessible routes and equipped with at least one accessible fixture of each type. In toilet rooms with partitioned water closet compartments, at least one compartment must be *wheelchair accessible*. Where six or more compartments are provided, one additional compartment must be *ambulatory accessible*, that is, be at least 36 in. (914 mm) in width, have an outward-swinging door, and be equipped with grab bars. Where sinks are provided, at least 5% (and at least one) must be accessible. Where only one urinal is provided, it need not be accessible.

Where drinking fountains are provided, at least half must be accessible. At a minimum, at least two accessible fountains are required, one for wheelchair-bound users and one for standing users. Alternatively, a single fountain complying with the dimensional requirements for both user types may be provided.

In A Assembly and M Mercantile Occupancies where a total of six or more water closets are required, at least one accessible, unisex family, or assisted-use toilet room must be provided for individuals and their assistants. In recreational facilities with separate-sex bathing rooms with more than two bathtubs or showers total, at least one such unisex bathing room must be provided. These facilities should have only one set of each fixture type. They must be located on accessible routes, not more than one story above or below other separate-sex toilet or bathing rooms, with a maximum travel distance along the accessible route of 500 ft (152 m) from those rooms. The fixtures provided in accessible unisex toilet and bathing rooms may be counted toward the overall fixture requirements of the space.

# VERTICAL DISTRIBUTION OF SERVICES FOR LARGE BUILDINGS

| Occupancy | Water Closets | Lavatories | Drinking Fountains | Bathrooms/ Showers |
|---|---|---|---|---|
| **A: Assembly** | | | | |
| A-1: Theaters, motion pictures, and performing arts facilities | Male: 1 per 125<br>Female: 1 per 65 | 1 per 200 | 1 per 500 | None |
| A-2: Nightclubs, bars, taverns, dance halls | 1 per 40 | 1 per 75 | 1 per 500 | None |
| A-2: Restaurants, banquet halls, food courts | 1 per 75 | 1 per 200 | 1 per 500 | None |
| A-3: Auditoriums without fixed seating, galleries, museums, exhibition halls, museums, lecture halls, libraries, arcades, gymnasiums | Male: 1 per 125<br>Female: 1 per 65 | 1 per 200 | 1 per 500 | None |
| A-3: Places of worship | Male: 1 per 150<br>Female: 1 per 75 | 1 per 200 | 1 per 1000 | None |
| A-3: Passenger terminals and transportation facilities | 1 per 500 | 1 per 750 | 1 per 1000 | None |
| A-4 and A-5: Indoor and outdoor arenas with up to 1500 seats | Male, first 1500 seats: 1 per 75<br>Female, first 1500 seats: 1 per 40<br>Additional seating:<br>Male: 1 per 120<br>Female: 1 per 60 | Male: 1 per 200<br>Female: 1 per 150 | 1 per 1000 | None |
| **B: Business** | First 50 occupants: 1 per 25<br>Additional occupants: 1 per 50 | First 80 occupants: 1 per 40<br>Additional occupants: 1 per 80 | 1 per 100 | None |
| **E: Educational** | 1 per 50 | 1 per 50 | 1 per 100 | None |
| **F: Factory** | 1 per 100 | 1 per 100 | 1 per 400 | Emergency showers and eyewash stations may be required |
| **I: Institutional** | | | | |
| I-1: Residential care | 1 per 10 | 1 per 10 | 1 per 100 | 1 per 8 |
| I-2: Hospitals, ambulatory nursing homes (residents only) | 1 per room, or<br>Two patient rooms may share one toilet room with direct access from each room | 1 per room, or | 1 per 100 | 1 per 15 |
| I-2: Visitors | 1 per 75 | 1 per 100 | 1 per 500 | |
| I-3: Prisons (residents only) | 1 per cell | 1 per cell | 1 per 100 | 1 per 15 |
| I-3: Reformatories, detention centers, correctional centers (residents only) | 1 per 15 | 1 per 15 | 1 per 100 | 1 per 15 |
| I-2 and I-3: Employee toilet facilities | 1 per 25 | 1 per 35 | 1 per 1000 | None |
| I-4: Adult and child day care | 1 per 15 | 1 per 15 | 1 per 100 | 1 |
| **M: Mercantile** | 1 per 500 | 1 per 750 | 1 per 1000 | None |
| **R: Residential** | | | | |
| R-1: Hotels and motels | 1 per sleeping unit | 1 per sleeping unit | None | 1 per sleeping unit |
| R-2: Dormitories, fraternity houses, sorority houses, boarding houses | 1 per 10 | 1 per 10 | 1 per 100 | 1 per 8 |
| R-2: Apartments | 1 per dwelling unit | 1 per dwelling unit | None | 1 per dwelling unit |
| R-3: Congregate living facilities with 16 or fewer persons | 1 per 10 | 1 per 10 | 1 per 100 | 1 per 8 |
| R-3: One- and two-family dwellings | 1 per dwelling unit | 1 per dwelling unit | None | 1 per dwelling unit |
| R-4: Residential care, assisted living facilities | 1 per 10 | 1 per 10 | 1 per 100 | 1 per 8 |
| **S: Storage (not including parking)** | 1 per 100 | 1 per 100 | 1 per 1000 | Emergency showers and eyewash stations may be required |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## Minimum Plumbing Fixture Requirements in the National Building Code of Canada

Consult the table on the facing page to determine the minimum number of plumbing fixtures required by the National Building Code of Canada, based on the Occupancy classification and number of occupants served. See pages 13–17 for more information on determining Occupancy classifications for your building and page 297 for determining the occupant load.

In determining fixture requirements, the following should also be considered:

- Fixture requirements should be based on the assumption of equal numbers of male and female occupants, unless an unequal distribution of the sexes in the occupant population can be demonstrated with reasonable accuracy.
- Under most circumstances, separate toilet facilities are required for each sex. Separate facilities are not required for the following Occupancies with an occupant load of 10 or less: Assembly, B-3 Care, Residential, Business and Personal Services, Mercantile, and Industrial.
- For male toilet facilities, urinals may be substituted for up to two-thirds of the required water closets.
- For Business and Personal Service Occupancies with a floor area of more than 600 m$^2$ (6460 sq ft), toilet facilities must be available to the public.

## Accessible Toilet Facilities in the National Building Code of Canada

Most buildings must provide at least one accessible, barrier-free washroom. All washrooms on floors requiring barrier-free access must themselves be barrier-free, except that barrier-free washrooms are not required:

- Within a B-3 Care or C Residential Occupancy suite
- Where other barrier-free facilities are located on the same floor area and within a path of travel of 45 m (148 ft)
- Within D Business and Personal Services, E Mercantile, and F Industrial Occupancies, individual suites less than 500 m$^2$ (5380 sq ft) in area that are completely separated from the rest of the building

Where showers are provided, at least one barrier-free stall must be provided, except in B-3 Care and C Residential Occupancy suites. Where drinking fountains are provided, at least one barrier-free fountain must be provided.

Special barrier-free, single-fixture, unisex *universal toilet rooms* may be provided as an alternative to providing barrier-free facilities within single-sex facilities. When universal toilet rooms are provided, the occupant load used to calculate fixture requirements for the general public may be reduced by 10 persons in Assembly, Business and Personal Services, Mercantile, or Industrial Occupancies, as well as in primary schools, day care facilities, places of worship, and undertaking premises. If only one universal toilet room is provided, the water closet in that room generally may not be counted toward the water closet requirements of the building.

# VERTICAL DISTRIBUTION OF SERVICES FOR LARGE BUILDINGS

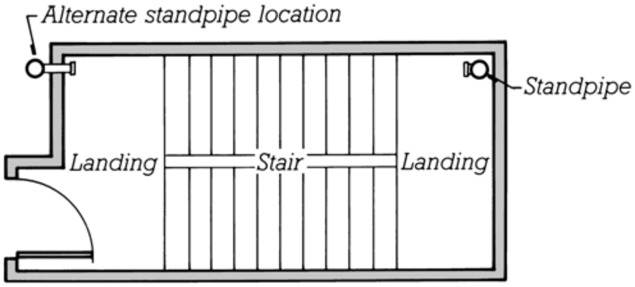
| Occupancy | Number of Occupants of Each Sex | Number of Water Closets for Each Sex | Number of Lavatories |
|---|---|---|---|
| **A: Assembly** | | | |
| Assembly spaces, except those listed below | 1–25 | Male: 1; Female: 1 | At least 1, and not less than 1 per every 2 water closets |
| | 26–50 | Male: 1; Female: 3 | |
| | 51–75 | Male: 2; Female: 3 | |
| | 76–100 | Male: 2; Female: 4 | |
| | 101–125 | Male: 3; Female: 5 | |
| | 126–150 | Male: 3; Female: 6 | |
| | 151–175 | Male: 4; Female: 7 | |
| | 176–200 | Male: 4; Female: 8 | |
| | 201–250 | Male: 5; Female: 9 | |
| | 251–300 | Male: 5; Female: 10 | |
| | 301–350 | Male: 6; Female: 11 | |
| | 351–400 | Male: 6; Female: 12 | |
| | Over 400 | Male: 7 plus 1 for each additional increment of 200 occupants over 400<br>Female: 13 plus 1 for each additional increment of 100 occupants over 400 | |
| Primary schools and day care centers | Any number | Male: 1 per 30<br>Female: 1 per 25 | Same as above |
| Places of worship, undertaking premises | Any number | 1 per 150 | Same as above |
| **B: Care and Detention** | | | |
| B-1, B-2: Detention, medical treatment facilities | Any number | Based on the specific needs of the occupants, determined on a case-by-case basis | Same as above |
| B-3: Care facilities | Any number | 1 per 10 | Same as above |
| **C: Residential** | | | |
| Except dwelling units | Any number | 1 per 10 | Same as above |
| Dwelling units | Any number | 1 per unit | Same as above |
| **D: Business and Personal Services** | 1–25<br>25–50<br>Over 50 | 1 for each sex<br>2 for each sex<br>3 plus 1 for each additional increment of 50 occupants over 50 | Same as above |
| **E: Mercantile** | Any number | Male: 1 per 300<br>Female: 1 per 150 | Same as above |
| **F: Industrial** | 1–10 | 1 | Same as above |
| | 11–25 | 2 | |
| | 26–50 | 3 | |
| | 51–75 | 4 | |
| | 76–100 | 5 | |
| | Over 100 | 6 plus 1 for each additional increment of 30 occupants over 100 | |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## STANDPIPES

A *standpipe* is a large-diameter steel water pipe extending vertically through a building, with fire hose connections at every floor. There are three basic types: A *wet standpipe* is continuously filled with water. A *dry standpipe* normally contains no water. In the case of a building fire, water may be supplied to it automatically, by a fire control system, or manually, by connecting fire department pumper trucks to connections on the front of the building at street level. A *combination standpipe*, normally wet, supplies water to the building's sprinkler system as well as to required fire hose connections. In addition to providing connections for hoses carried into the building by firefighters, standpipes may be prefitted with permanent lighter-duty hoses intended for early fire suppression efforts before larger hoses arrive. Depending on the standpipe type, the minimum nominal diameter is 4 to 6 in. (100 to 150 mm).

Building code standpipe requirements vary with building height, area, occupancy, and the extent of sprinklers. The International Building Code generally requires standpipes in buildings with floors more than 30 ft (9.1 m) above or below the level of firefighter access and includes special requirements for assembly spaces, covered malls, underground buildings, parking garages, and other unique occupancy conditions. The National Building Code of Canada requires standpipes in buildings with more than three stories, with top story ceilings more than 14 m (46 ft) above grade, and in shorter buildings in which certain occupancies exceed 1000 m$^2$ (10,800 sq ft) or more in area per floor. See the appropriate code for more details.



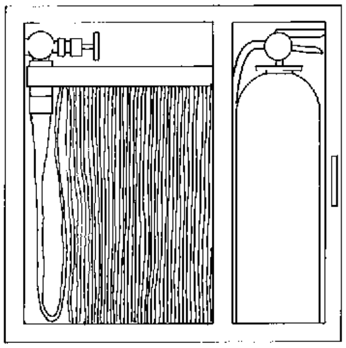
STANDPIPES WITHIN AN EXIT STAIR ENCLOSURE

Where standpipes are required, they must be provided in every exit enclosure. Where remote portions of a story are located more than 150 to 200 ft (45 to 60 m) from the nearest standpipe connection in an exit, additional standpipes may be required to improve coverage. Hose connections to the standpipe may be located on stair landings between floors, such that each connection can serve two levels.

Where floor levels are not sprinklered, additional *hose stations*, cabinets with prefitted hoses, may also be required, dispersed so as to provide full coverage of the floor area. Portable fire extinguishers are often incorporated into these cabinets. A typical recessed wall cabinet for a wet standpipe hose and a fire extinguisher is 2 ft 9 in. (840 mm) wide, 9 in. (230 mm) deep, and 2 ft 9 in. (840 mm) high.

Building fire sprinklers may be served by wet standpipes dedicated solely to the sprinkler system or combination standpipes. From the standpipe, horizontal piping branches at each floor and, if it is concealed, runs just above the finish ceiling. An assembly of valves and alarm fittings is furnished at the point where the sprinkler system joins the domestic water system, usually in the same room with the domestic water pumps.

In the case of a significant building fire, the building's water supply may become overwhelmed and unable to provide sufficient water to both sprinklers and standpipes for fire hoses. To prevent this, the water supply to these systems is augmented by firefighter pumper trucks drawing water from nearby fire hydrants and delivering it to standpipe connections, either Y-shaped *Siamese connections* on the outside of the building or smaller interior *floor outlets*.



HOSE CABINET

SIAMESE CONNECTION

## DESIGNING ELEVATORS AND ELEVATOR LOBBIES

The tables to the right can be used to arrive at an approximate number of elevators and appropriate sizes for the cars. In very tall buildings, the number of shafts can be reduced by as much as one-third with schemes of express and local elevators or advanced control systems.

Walking distance from the elevator lobby to any room should not exceed 150 ft (45 m). In many buildings, elevators also must be sized to comply with building code requirements for accommodating persons with disabilities or emergency aid personnel with medical stretchers. For more information, see page 282 for the International Building Code and page 286 for the National Building Code of Canada.

**APPROXIMATE NUMBERS OF ELEVATOR SHAFTS**

| Use | Number of Shafts | Capacity of Elevator |
|---|---|---|
| Apartment Buildings | 1 per 75 units, plus<br>1 service elevator for 300 units or more in a high-rise building | 2000 to 2500 lb<br>(900 to 1140 kg) |
| Hotels | 1 per 75 rooms, plus<br>1 service elevator for up to 100 rooms and<br>1 service elevator for each additional 200 rooms | 2500 to 3000 lb<br>(1140 kg to 1360 kg) |
| Office Buildings | 1 per 35,000 sq ft (3250 $m^2$) of area served, plus<br>1 service elevator per 265,000 sq ft (24,600 $m^2$) of area served | 2500 to 3500 lb<br>(1360 to 1590 kg) |

**ELEVATOR DIMENSIONS**

| Use | Capacity | Inside Car Dimensions | Inside Shaft Dimensions (width × depth) |
|---|---|---|---|
| Apartments, Hotels, Office Buildings, Stores | 2000 lb<br>(900 kg) | 5'-8" × 4'-3"<br>(1727 × 1295 mm) | 6'-7" × 7'-4"<br>(2006 × 2235 mm) |
| | 2500 lb<br>(1140 kg) | 6'-8" × 4'-3"<br>(2032 × 1295 mm) | 8'-4" × 6'-8"<br>(2540 × 2032 mm) |
| Office Buildings, Hotels, Stores | 3000 lb<br>(1360 kg) | 6'-8" × 4'-9"<br>(2032 × 1448 mm) | 8'-4" × 7'-5"<br>(2540 × 2261 mm) |
| Office Buildings, Stores | 3500 lb<br>(1590 kg) | 6'-8" × 5'-5"<br>(2032 × 1651 mm) | 8'-4" × 8'-1"<br>(2540 × 2464 mm) |
| Hospitals, Nursing Homes | 6000 lb<br>(2730 kg) | 5'-9" × 10'-0"<br>(1750 × 3050 mm) | 8'-2" × 11'-9"<br>(2490 × 3580 mm) |
| Freight, Service | 4000 to 6000 lb<br>(1820 to 2730 kg) | 8'-4" × 10'-0"<br>(2540 × 3050 mm) | 10'-10" × 10'-8"<br>(3300 × 3250 mm) |

### Laying Out Banks of Elevators

Elevators serving the same zone of the building should be arranged in a single bank so that waiting persons can keep all the doors in sight at one time. A bank of three in a row is the largest that is desirable; four in a row is acceptable. Banks of elevators serving different zones of the building may open on opposite walls of the same elevator lobby or onto separate lobbies. The minimum width of an elevator lobby serving a single bank of elevators is 8 ft (2.45 m); for a lobby with banks of elevators on both sides, the minimum width is 10 ft (3 m).

Building codes in some circumstances require elevator lobbies to be separated from surrounding floor areas to reduce the risk of smoke or fire spreading easily through the elevator shaft to adjacent floors. In the International Building Code, elevators serving more than three stories must generally be provided with protected lobbies. Some exceptions to this requirements include elevators in pressurized shafts, in most occupancies (other than I-2 or I-3) in buildings that are fully sprinklered and not considered high-rise (see page 291), or on ground floors when that floor level is sprinklered. In the National Building Code of Canada, except where elevators are within permitted interconnected floor space (see page 373), they must be separated from adjacent floor areas.

Elevator shafts are noisy and should not be located next to acoustically sensitive spaces—for example, sleeping or dwelling units in hotels and residential buildings.

Elevator cars ordinarily have doors on one side only. Cars with doors on opposing sides are available but necessitate a shaft that is slightly wider than normal to allow the counterweights to be placed next to the side of the car.

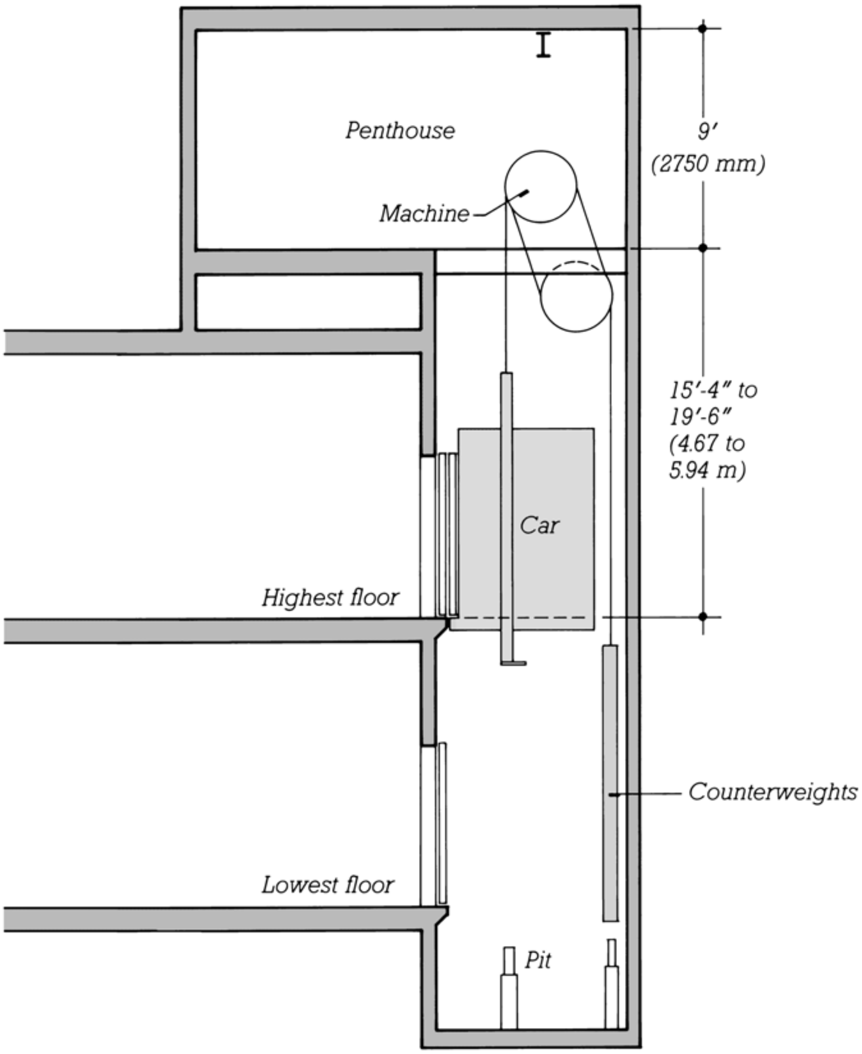
Freight and service elevators should open to separate service rooms or workrooms. Mailrooms, receiving rooms, and maintenance and housekeeping facilities should relate closely to service elevators.

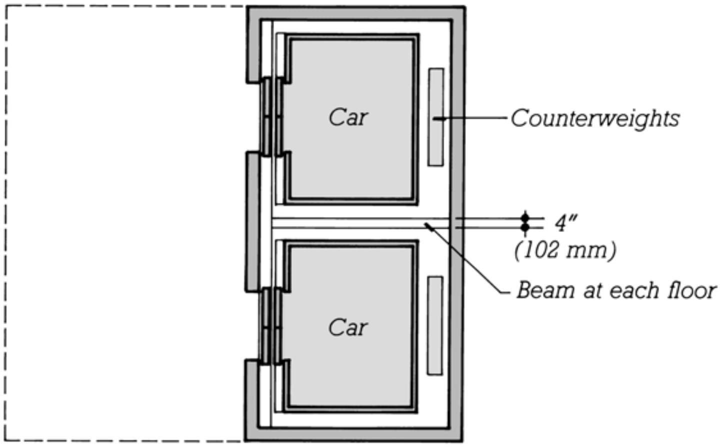
See the following page for information on elevator types, penthouses, pits, and machine rooms.

## ELEVATOR TYPES, PENTHOUSES, PITS, AND MACHINE ROOMS

The choice of elevator type is based on the height and number of floors served. For travel up to five floors and 40 to 60 ft (12 to 18 m), hydraulic elevators are usually the most economical. With this type, a hydraulic piston is located either in a drilled well at the bottom of the shaft or within the shaft itself. A machine room approximately 45 sq ft (4.2 m$^2$) in area is required, connected to the elevator shaft by hydraulic lines and electrical control wiring. Its preferred location is adjacent to the elevator shaft on the lowest level served by the elevator. However, the machine room is also noisy and should not be located close to acoustically sensitive areas. When necessary, it may be located on other levels or at a greater distance from the shaft. The inside top of the elevator shaft itself must extend 13–14 ft (3.9–4.25 m) above the uppermost finish floor level served; frequently this results in the shaft construction projecting at least several feet above adjacent roof areas. When referring to the Elevator Dimensions table on the previous page, inside shaft dimensions should be increased by 6 in. (150 mm) in width and reduced by 12 in. (300 mm) in depth from those listed to account for differences in the lifting machinery of this elevator type.

At greater heights, electric traction elevators are required. In its most common form, this type of elevator has its hoisting machinery located in a penthouse machine room above the top of the elevator shaft. This room's inside dimensions must be approximately 9 ft (2.7 m) high, as wide as the shaft itself, and 16–18 ft (5–5.5 m) long. It is located exactly over the top of the elevator shaft, extending





beyond the shaft on the side above the elevator doors. Below the elevator machine room, the inside top of the elevator shaft itself must extend from 15 to 20 ft (4.5 to 6.1 m) above the uppermost finish floor level served. For this reason, the penthouse must frequently be raised above the adjacent roof surface, making it a significant presence on the building rooftop.

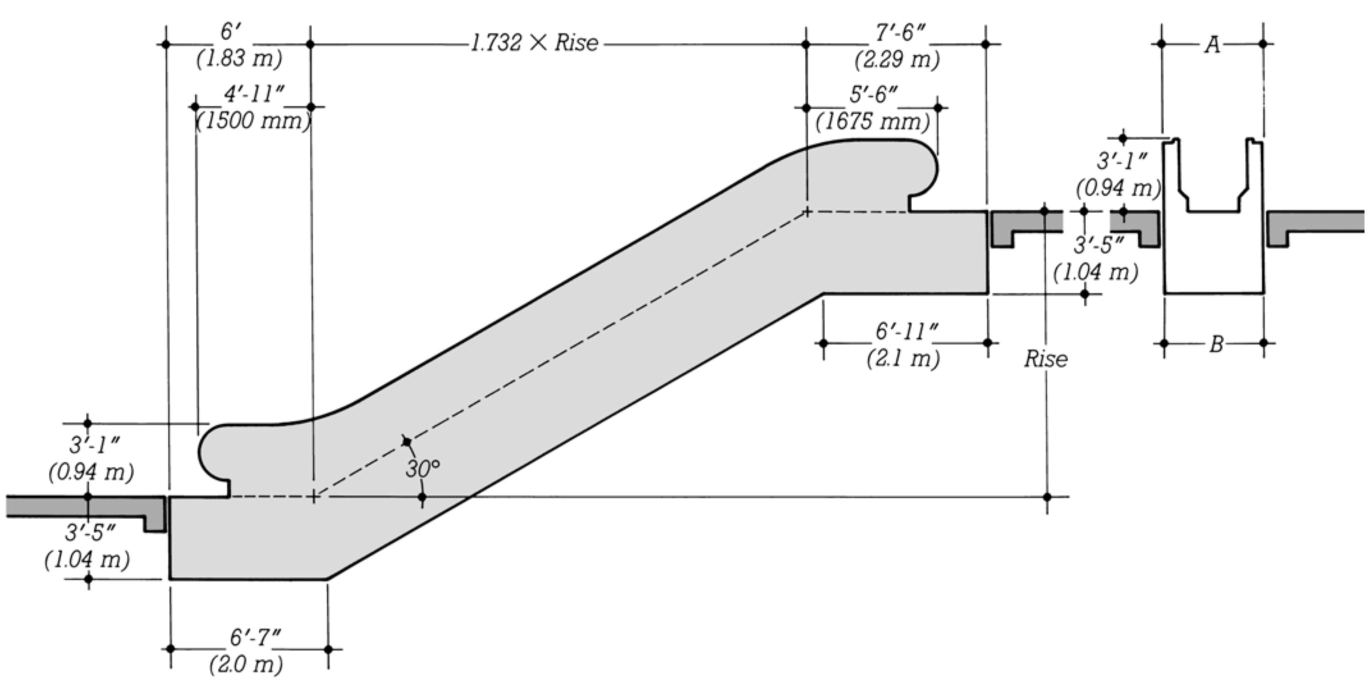
Another option for serving vertical distances up to 300 ft (90 m) is an electric traction elevator using relatively new, compact gearless hoisting machinery. With this type, the smaller hoisting motor is located within the elevator shaft itself. Sometimes referred to as *machine room-less*, these elevators are available in capacities of up to 4000 lb (1800 kg) for passenger service and 5000 lb (2300 kg) for hospital service or freight. For preliminary inside shaft dimensions, use the sizes listed in the Elevator Dimensions table on page 201. Machine room-less elevators require separate control rooms or closets. A space as little as 5 ft (1.5 m) deep directly adjacent to the elevator shaft may be sufficient for some systems. Or a room 25 to 90 sq ft (2.5 to 8 m$^2$) in area, depending on the number and capacity of elevators in operation, may be required. Most commonly, this closet or room is located adjacent to the elevator shaft, near its top. However, in some cases, it may be possible to locate this space as far as 100 ft (30 m) from the shaft. The minimum height required from the uppermost floor level served to the inside top of the shaft varies considerably among the available configurations; consult manufacturers' technical literature for more information. Machine room-less elevators are quieter than alternative types and consume significantly less electrical power.

Every elevator shaft must terminate with a pit at the bottom. For electric traction elevators, the inside depth of the pit below the lowest floor level served varies from approximately 5 to 13 ft (1.5 to 4 m), depending on the speed and capacity of the elevator—the bigger and faster the elevator, the deeper the pit. Hydraulic elevators normally require a pit 4 ft (1.2 m) deep.

## ESCALATORS

Escalators are useful in situations where large numbers of people wish to circulate among a small number of floors on a more or less continual basis. An escalator cannot be counted as a means of egress. The structural and mechanical necessities of an escalator are contained in the integral box that lies beneath the moving stairway. Structural support is required only at the two ends of the unit. Some basic dimensional information on escalators is tabulated below.

| | 32" Escalator | 48" Escalator |
|---|---|---|
| A | 3'-9"<br>(1145 mm) | 5'-1"<br>(1550 mm) |
| B | 3'-7"<br>(1090 mm) | 4'-11"<br>(1500 mm) |



## A CHECKLIST OF CORE COMPONENTS

The following is an alphabetical listing of components that are often incorporated into the cores of a building. For more information on any component, follow the accompanying page reference.

**Chimneys (page 180)**

**Drinking fountains and water coolers (pages 196–197)**

**Electrical closets (page 193)**

**Elevators (pages 201–203)**
- Dumbwaiters and vertical conveyors
- Elevator lobbies
- Freight elevators and freight rooms
- Passenger elevators
- Service elevators and service lobbies

**Escalators (page 203)**

**Fan rooms (pages 185–186)**

**Fire hose and fire extinguishers cabinets (page 200)**

**Janitor closets (page 195)**

**Kitchens**

**Mail facilities (page 194)**
- Mail chutes
- Mail conveyors
- Mailrooms

**Plumbing walls (including waste and vent pipes) (page 195)**

**Refuse facilities (page 188)**
- Refuse chute
- Refuse room

**Shafts (pages 190–195)**
- Domestic water piping:
  - Chilled drinking water supply and return piping
  - Domestic cold water supply and return piping
  - Domestic hot water supply and return piping
  - Liquid soap supply piping to toilet rooms
  - Supply riser to rooftop gravity tank
- Electrical and communications shafts:
  - Electrical wires or bus bars
  - First communications wiring: Alarms, smoke and heat detectors, firefighter communications
  - Telephone, telex, local area networks, cable television, community antenna, etc.
- Heating and cooling shafts:
  - Control wiring
  - Ducts (page 212)
    - Exhaust ducts from toilets, baths, janitor closets, shower rooms, locker rooms, storage rooms, kitchens, corridors, fume hoods, laboratory areas, workshop areas, industrial processes (page 184)
    - Fire exhaust and pressurization ducts
    - Outdoor air and exhaust air ducts to local fan rooms
    - Supply ducts (page 212)
    - Return ducts (page 212)
  - Piping
    - Air piping for controls
    - Chilled water supply and return
    - Condenser water supply and return between chilled water plant and cooling towers
    - Fuel oil piping
    - Gas piping
    - Hot water and/or steam supply and return
- Piping, miscellaneous: Compressed air, vacuum, deionized water, distilled water, fuel gas, medical gases, scientific gases, industrial gases
- Piping, plumbing waste and vent (page 195)
- Piping, storm drainage risers from roofs and balconies

**Sprinkler riser (page 200)**

**Stairways (pages 274–277)**

**Standpipes, fire (page 200)**

**Structure (pages 21–135)**
- Beams and girders, including special support around shafts and under heavy equipment
- Bracing
- Columns
- Shear walls

**Telecommunications closets (page 193)**

**Toilet rooms (pages 195–199)**

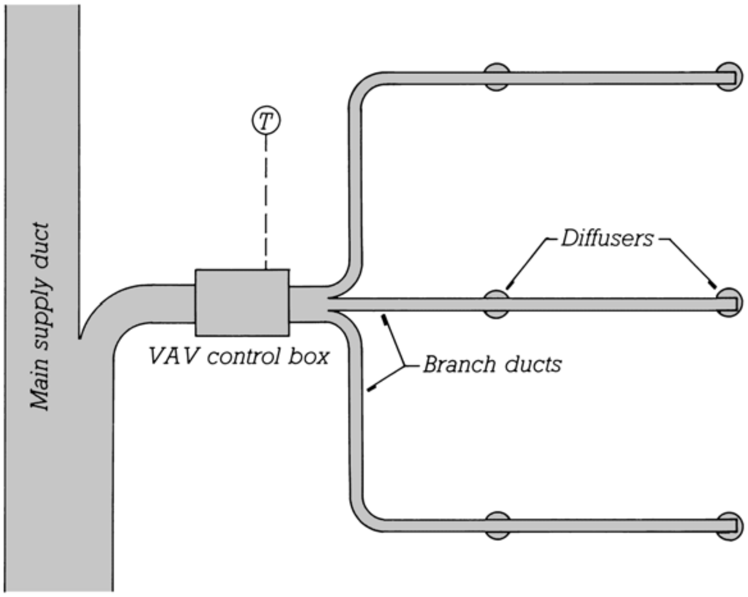
# HORIZONTAL DISTRIBUTION OF SERVICES FOR LARGE BUILDINGS

The horizontal distribution system for mechanical and electrical services in a large building should be planned simultaneously with the structural frame and the interior finish systems, because the three are strongly interrelated. The floor-to-floor height of a building is determined in part by the vertical dimension needed at each story for horizontal runs of ductwork and piping. The selection of finish ceiling, partition, and floor systems is often based in part on their ability to contain the necessary electrical and mechanical services and to adjust to future changes in these services. All these strategies involve close cooperation among the architect and the structural and mechanical engineers.

## CONNECTING HORIZONTAL AND VERTICAL DISTRIBUTION LINES

Horizontal mechanical and electrical lines must be fed by vertical lines through smooth, functional connections. Plumbing waste lines, which must be sloped to drain by gravity, have top priority in the planning of horizontal service lines; if they are confined to vertical plumbing walls, they will not interfere with other services. Sprinkler heads, which have the second highest priority in the layout of horizontal services, are served from the fire standpipe by horizontal piping that seldom exceeds 4 in. (100 mm) in outside diameter. The spacing of the heads is coordinated with the placement of walls and partitions; the maximum coverage per head is about 200 sq ft (18.6 m$^2$) in light-hazard buildings such as churches, schools, hospitals, office buildings, museums, apartment houses, hotels, theaters, and auditoriums. Coverage in industrial and storage buildings ranges from 130 to 90 sq ft (12.1 to 8.4 m$^2$) per head, depending on the substances handled in the building.

Air conditioning ducts, the next priority, branch out from a local fan room or from vertical ducts in supply and return shafts. Return ducts are often very short and confined to the interior areas of the building. Supply ducts extend from the main ducts through VAV or mixing boxes, then through low-velocity secondary ducts to air diffusers throughout the occupied area of the floor, with special emphasis on the perimeter, which may be on an independent, separately zoned set of ducts. Diffusers are generally required at the rate of four to seven diffusers per 1000 sq ft (100 m$^2$). For some typical diffuser designs, see the illustration on page 209.



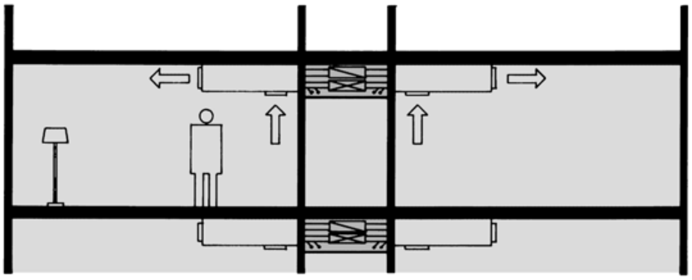
**PLAN OF VAV DUCTING**

## GROUPED HORIZONTAL DISTRIBUTION

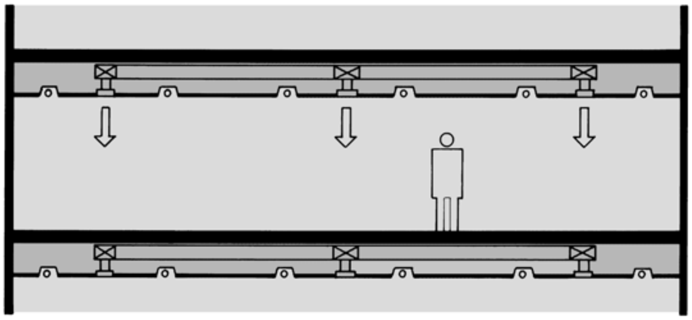
Sometimes the major runs of ductwork, piping, and wiring can be grouped in the ceiling area above the central corridor of each floor of a building, leaving the ceilings of the surrounding rooms essentially "clean." This works especially well in hotels, dormitories, and apartment buildings that rely on above-ceiling all-water or electric equipment in the area adjacent to the corridor for heating, cooling, and ventilating. A low corridor ceiling is readily accepted in exchange for high, unobstructed space in the occupied rooms, where the structure may be left exposed as the finish ceiling, saving cost and floor-to-floor height. If the building has a two-way flat plate or hollow core precast slab floor structure, the overall thickness of the ceiling–floor structure can be reduced to as little as 8 in. (200 mm). Conduits containing wiring for the lighting fixtures may be cast into the floor slabs or exposed on the surface of the ceilings. Wiring to wall outlets is easily accommodated in permanently located partitions.

## FLOORWIDE HORIZONTAL DISTRIBUTION

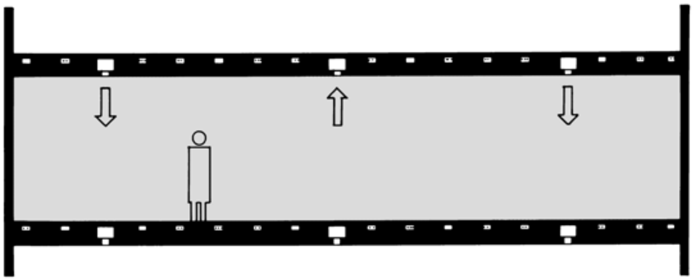
In broad expanses of floor space, particularly where all electrical and communications services must be available at any point in the area, an entire horizontal layer of space is reserved on each story for mechanical and electrical equipment. This layer may be beneath a raised access floor just above the structural floor. It may also lie within the structural floor or just beneath the floor, above a suspended ceiling. Sometimes combinations of these locations are used.



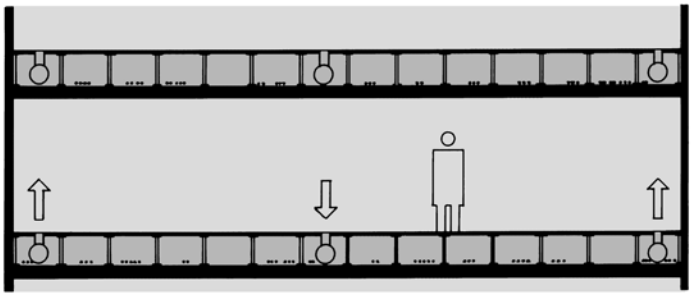
GROUPED HORIZONTAL DISTRIBUTION
OVER A CENTRAL CORRIDOR



FLOORWIDE ABOVE-CEILING
HORIZONTAL DISTRIBUTION



FLOORWIDE IN-FLOOR
HORIZONTAL DISTRIBUTION



FLOORWIDE RAISED ACCESS FLOOR
HORIZONTAL DISTRIBUTION

# HORIZONTAL DISTRIBUTION OF SERVICES FOR LARGE BUILDINGS

## Distribution above a Suspended Ceiling

Above a ceiling, wiring is run in conduits or cable trays attached to the structure above. Lighting fixtures are served directly from this horizontal wiring. Outlets on the floor below may be served by electrified partitions or power poles. Outlets on the floor above may be fed via poke-through fixtures that are cut through the structural floor. Poke-through fixtures can be added or removed at any time during the life of the building; their major disadvantage is that electrical work being done for the convenience of a tenant on one floor is done at the inconvenience of the tenant on the floor below.

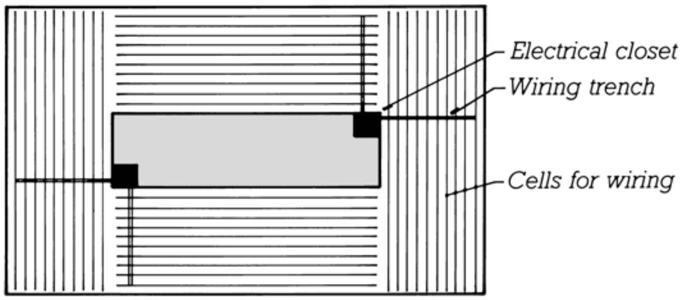
## Distribution within the Structural Floor

Electrical and communications wiring may be embedded in the floor slab in conventional conduits. For greater flexibility in buildings where patterns of use are likely to change over time, systems of cellular steel decking over steel framing, or cellular raceways cast into a topping over concrete slabs, may be selected. These provide a treelike structure: The trunk is a wiring trench that runs from the electrical closet to the outside wall of the building, and the branches are the hollow cells that run in the perpendicular direction. Electrical and communications wires and outlets can be added, removed, or changed at any time during the life of the building. Cellular steel decking can affect the layout of the beams and girders in a steel-framed building: For optimum distribution of wiring, the cells in the decking generally run parallel to the wall of the core, and for structural reasons the cells must run perpendicular to the beams. This requires close coordination among the architect and the electrical and structural engineers.

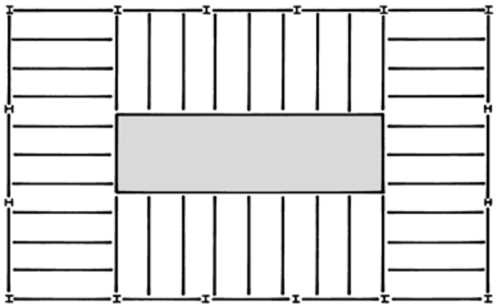
## Distribution above the Structural Floor

A raised access floor system allows maximum flexibility in running services because it can accommodate piping, ductwork, and wiring with equal ease. It is especially useful in industrial or office areas where large numbers of computers or computer terminals are used and where frequent wiring changes are likely. It is also valuable in retrofitting old buildings for modern services. Though floors can be raised to any desired height above the structural deck, heights of 4 to 8 in. (100 to 200 mm) are most common. Less costly, lower-profile systems, ranging from 2½ to 3 in. (65 to 75 mm) in height, are also available.

Undercarpet flat wiring may be used instead of a raised access floor in buildings with moderate needs for future wiring changes. Flat wiring does not increase the overall height of the building, as raised access floors usually do, but it does not offer the unlimited capacity and complete freedom of wire location of the raised floors. Flat wiring is used in both new buildings and retrofit work.

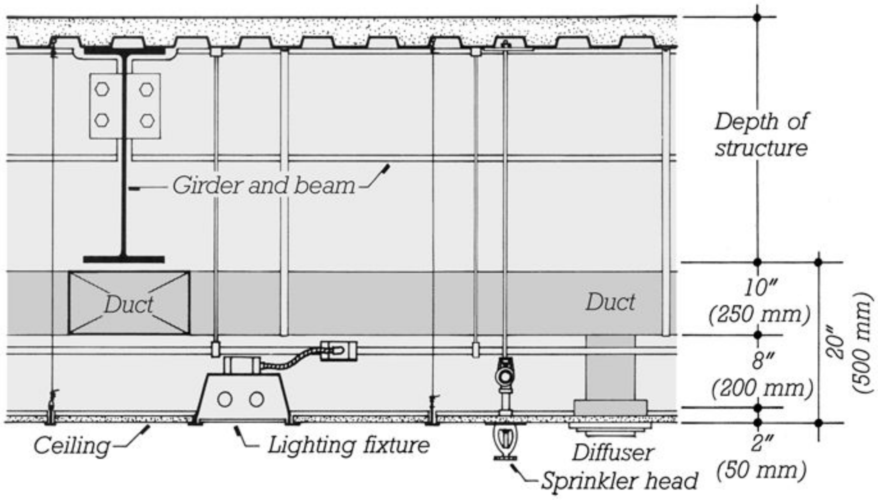


PLAN OF CELLULAR STEEL DECKING



STEEL FRAMING PLAN FOR CELLULAR STEEL DECKING

## DESIGNING THE CEILING/FLOOR PLENUM SPACE



SECTION THROUGH A CEILING/FLOOR ASSEMBLY

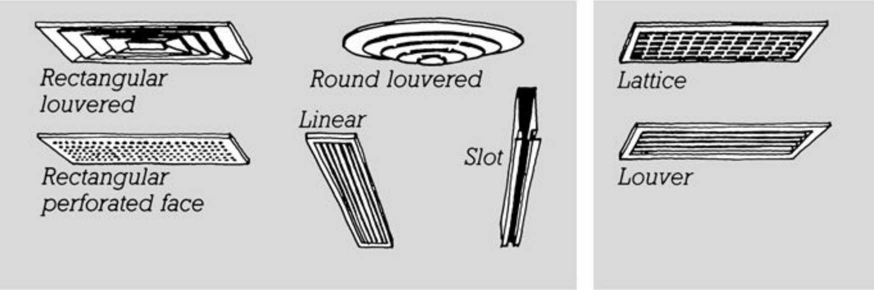
Ductwork, which is often too large and bulky to fit above or within the structural floor, is ordinarily best located above the ceiling. There, it must share the above-ceiling plenum space with structural members and other systems. This requires careful planning. Generally, the lowest stratum, about 8 in. (200 mm) thick, is reserved for the sprinkler piping and lighting fixtures. Lighting fixture selection plays an important role in determining the thickness of this stratum, because some types of lighting fixtures require more space than others. The ducts, which are usually 8 to 10 in. (200 to 250 mm) deep, run between this layer and the beams and girders. Adding about 2 in. (50 mm) for the thickness of a suspended ceiling, we see that a minimum height of about 18 in. (460 mm), and preferably 20 in. (500 mm), must be added to the thickness of the floor structure and fireproofing in a typical building to allow for mechanical and electrical services. A larger dimension is often called for, depending on the requirements of the combination of systems that is chosen.

As an example, let us assume that a steel-framed building has a maximum girder depth of 27 in. (690 mm) and a 4-in. (100-mm) floor slab, for a total floor structure height of 31 in. (790 mm). Adding 20 in. (510 mm) for ceiling and services, we arrive at an overall ceiling-to-floor height of 51 in. (1300 mm) that must be added to the desired room height to give the floor-to-floor height of the building. If fireproofing must be added to the girders, this dimension will increase by a couple of inches (50 mm or so).

There is tremendous economic pressure to reduce this height to a practical minimum in a tall building. A few inches saved per floor adds up to significant savings in the cost of the structure, core components, and cladding. Sometimes it is possible to arrange the framing so that ductwork never passes beneath a girder. If the ductwork must cross the girders, the designers should explore such options as shallower ducts, running the ducts through holes cut in the webs of the girders, or reducing the depth of the girders by using a heavier steel shape. In the average tall office building, the height of the ceiling/floor assembly is about 46 in. (1170 mm).

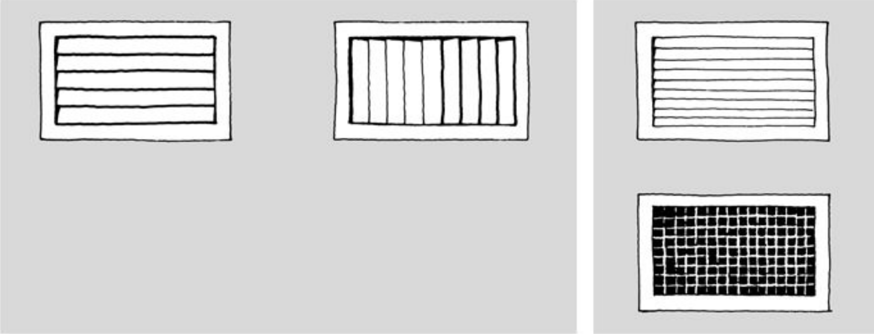
In some medical, research, and industrial buildings, the underfloor services are unusually complex, bulky, and subject to change. In these cases, the layer above the ceiling and below the floor structure is expanded to a height that allows workers to walk freely in it, and the ceiling is strengthened into a structure that can support their weight. Such an *interstitial ceiling* allows workers to maintain and change the services without disrupting the occupied spaces above or below.

With all its service penetrations—lighting fixtures, air diffusers and grilles, sprinkler heads, smoke detectors, intercom speakers—a ceiling can take on a visually chaotic appearance. It is advisable to compose the relationships of these penetrations carefully on a reflected ceiling plan.



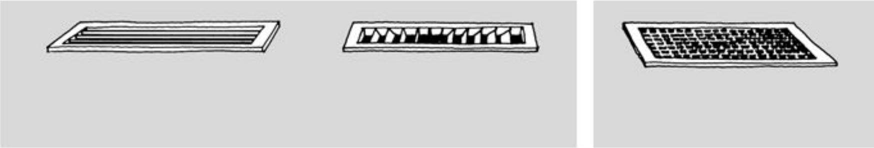
**CEILING SUPPLY DIFFUSERS**

**CEILING RETURN GRILLES**



**WALL REGISTERS**

**WALL RETURN GRILLES**



**FLOOR REGISTERS**

**FLOOR RETURN GRILLE**

TYPICAL GRILLE AND DIFFUSER DESIGNS

## EXPOSED VERSUS CONCEALED SERVICES

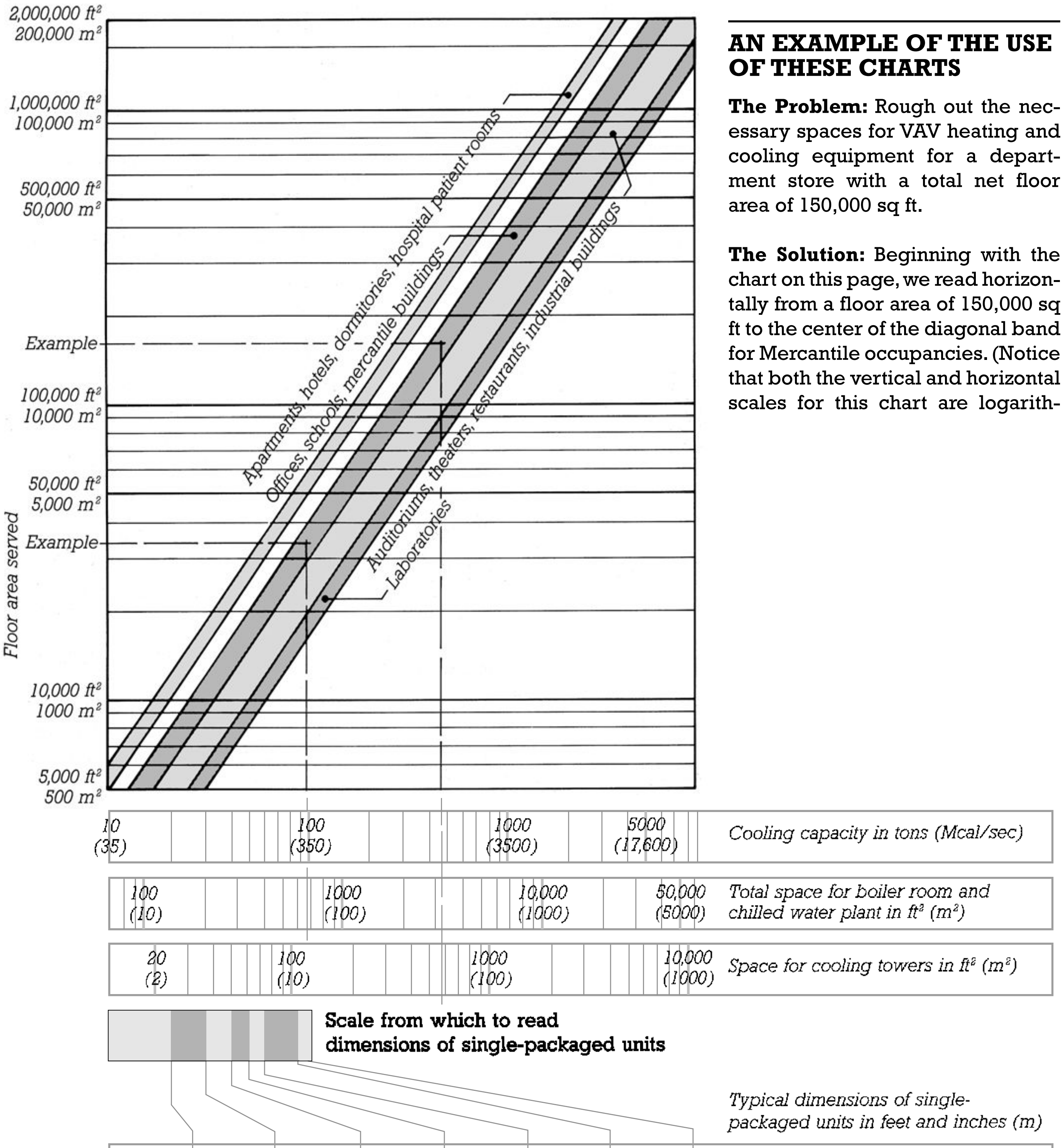
In many buildings, the designer has a choice between exposing the mechanical and electrical services and concealing them above a suspended ceiling. Exposed services are the rule in warehouses and industrial buildings. In other types of buildings, exposed pipes and ducts can have an attractive sculptural complexity. They are easy to reach for maintenance and revision. They make sense in many large, open buildings (athletic arenas, exhibition halls), as well as in certain other kinds of buildings in which full-height partitions are not often changed and a frank, functional appearance is appropriate (schools, art galleries, pubs and restaurants, avant-garde stores). There are some disadvantages: Exposed services that must look good are more expensive to design and install. If they are painted, this cost must be added. They also need to be cleaned from time to time. Although exposed services are readily accessible for changes, such changes must be made with care. For these reasons, it is usually cheaper to install a suspended ceiling than to omit one.

# SIZING SPACES FOR MAJOR HEATING AND COOLING EQUIPMENT

## AN EXAMPLE OF THE USE OF THESE CHARTS

**The Problem:** Rough out the necessary spaces for VAV heating and cooling equipment for a department store with a total net floor area of 150,000 sq ft.

**The Solution:** Beginning with the chart on this page, we read horizontally from a floor area of 150,000 sq ft to the center of the diagonal band for Mercantile occupancies. (Notice that both the vertical and horizontal scales for this chart are logarith-



*Typical dimensions of single-packaged units in feet and inches (m)*

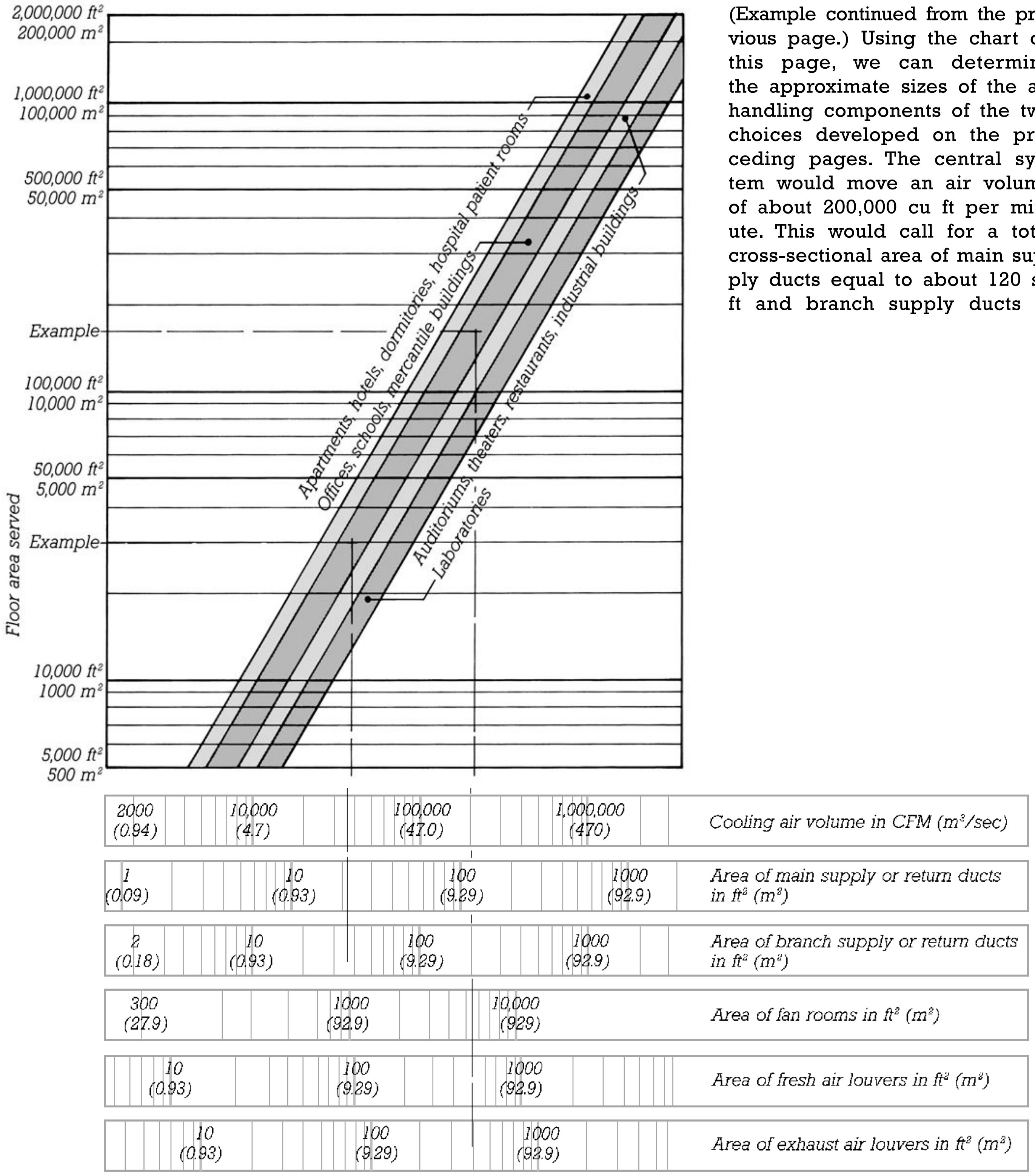
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10′-10″ (3.30) | 17′-1″ (5.21) | 20′-6″ (6.25) | 25′-0″ (7.62) | 25′-0″ (7.62) | 36′-3″ (11.05) | 39′-3″ (11.96) | Length |
| 7′-3″ (2.21) | 7′-3″ (2.21) | 7′-3″ (2.21) | 7′-3″ (2.21) | 7′-3″ (2.21) | 7′-8″ (2.34) | 7′-8″ (2.34) | Width |
| 4′-11″ (1.50) | 4′-11″ (1.50) | 4′-11″ (1.50) | 4′-11″ (1.50) | 4′-11″ (1.50) | 7′-9″ (2.36) | 7′-9″ (2.36) | Height |

mic; 150,000 lies much closer to 200,000 than to 100,000.) Reading down, we find that the required cooling capacity for this building is approximately 450 tons, requiring a chilled water plant and a boiler room that together will occupy an area of approximately 3200 sq ft. Cooling towers will occupy about 560 sq ft on the roof or alongside the building. The width of the diagonal band from which we have read gives us a range of 400 to 520 tons for the cooling requirement, so we know that these space requirements may grow somewhat smaller or larger as the system is designed in detail.

These values assume a central plant for heating and cooling. Could rooftop single-packaged units be used instead? We see at the bottom of the chart that no single-packaged unit is large enough to handle the entire load. Starting from the largest available packaged unit and reading up, we intersect the diagonal band and read to the left to find that the unit could serve about 33,000 sq ft of this building. Five such units could be distributed about the roof to furnish heating and air conditioning for the entire building, each serving about 30,000 sq ft. Each unit would need a capacity of about 90 tons and would measure 39 ft 3 in. long, 7 ft 8 in. wide, and 7 ft 9 in. high. A larger number of smaller units could also be used.

For more detailed information on boiler rooms, see page 180. Chilled water plants and cooling towers are explained on page 181 and single-packaged units on page 186.

Move to the following page to continue this example.



(Example continued from the previous page.) Using the chart on this page, we can determine the approximate sizes of the air handling components of the two choices developed on the preceding pages. The central system would move an air volume of about 200,000 cu ft per minute. This would call for a total cross-sectional area of main supply ducts equal to about 120 sq ft and branch supply ducts of about 200 sq ft total. If the branch supply ducts were 2 ft deep, for example, their aggregate width would be about 100 ft. Similar areas of return ducting would also be needed. Reading from the last three scales, we further determine that fan rooms totaling about 5200 sq ft are needed, served by fresh air louvers adding up to about 500 sq ft in area and exhaust air louvers totaling nearly 400 sq ft. The location and distribution of this louver area on the outside surfaces of the building are of obvious architectural importance.

Each of the rooftop single-packaged units would need about 21 sq ft of main duct for supply air and the same for return, with a total area of 35 sq ft for branch ducts. Fans and louvers are incorporated into the units and do not need to be provided separately.

For further information on fan rooms and louvers, see page 185.

# 3

# PASSIVE HEATING AND COOLING SYSTEMS

***This chapter will help you select and design passive heating and cooling systems for small and medium-sized buildings appropriate to your project's climate zone and building type.***

# PASSIVE HEATING AND COOLING DESIGN

Passive heating and cooling rely on natural systems to maintain a comfortable interior environment for building occupants. Solar radiation may be used as a source of heat for warmth. Naturally driven air currents can cool bodies directly or transport volumes of air at different temperatures into or out of a building. The thermal capacity of building materials can be exploited to reduce temperature extremes or capture thermal energy for later reuse. The evaporation of water can be used to cool and humidify hot, dry air.

By reducing reliance on active systems powered by fossil fuels or electricity, passive systems reduce building energy consumption and the production of greenhouse gasses. They rely on a minimum number of moving parts and are simple to maintain. They can also provide building occupants with the pleasure of a closer connection to the natural environment.

Passive heating and cooling strategies are best suited to small and medium-sized buildings and, in particular, those in which building form, orientation, and interior configuration can be molded to the requirements of these systems, as explained in more detail on the following pages. Large buildings, especially those with a high ratio of interior volume to exterior wall and roof area, are generally better suited to conventional mechanically driven heating and cooling systems. Conventional active systems are also generally a better choice where:

- Precise control over air temperature or humidity is required
- Air quality must be strictly controlled
- Interior spaces must be acoustically and visually isolated from each other and from their surroundings
- Heating or cooling loads are high or highly variable

## PASSIVE DESIGN STRATEGIES

On the following pages, you will find preliminary guidelines for selecting and designing passive heating and cooling systems suitable to various building types and climates. For any passive design, consider the simple strategies listed below so as to take maximum advantage of the natural environment and minimize building energy consumption.

### Cold Climates

Protect against the cold winter winds:

- Avoid hilltops, north-facing slopes, narrow valley bottoms, and other locations exposed to concentrated or fast-moving winds.
- Identify the direction of prevailing winter winds and take advantage of topography, planted barriers, or other natural or human-made features to shelter your building.
- Avoid large north-facing or windward-facing glass areas.
- Shape your building to shelter outdoor public spaces from winter winds.

Take advantage of the winter sun:

- Site and orient your building for good access to the winter sun. (See page 148 for more information.)
- Configure glazed openings to maximize the potential for winter solar heat gain.
- Use glazing with appropriate light transmittance and thermal performance characteristics.
- Use building materials with high heat capacity to store the sun's warmth during the day and release it back into the interior during cooler nights.

Minimize heat loss through the building enclosure:

- Consider compact building forms that reduce the area of the building enclosure in relation to its volume.
- Arrange secondary-use spaces (utility rooms, etc.) within the building to act as buffers to its colder north-facing or windward sides.
- Design and detail the building enclosure to minimize heat loss and uncontrolled air leakage.

### Hot Climates

Exploit the prevailing summer winds:

- Site and orient the building to take advantage of natural ventilation. (See pages 225–227 for more information.)
- Use amply sized, well-placed exterior openings and open interior plans to promote natural ventilation within the building.

Protect against the summer sun:

- Use trees and other vegetation to shelter the building from the summer sun.
- Design building overhangs and exterior shades to block the entry of the summer sun.
- Avoid overexposure to low early- and late-day sun.
- Avoid unshaded large east- and west-facing glazed areas.
- Use glazing materials with appropriate shading and thermal performance characteristics.
- Use exterior light-colored or reflective materials with care to avoid reflecting glare or heat into the building.
- Use building forms or groupings to create strategically shaded exterior public areas.

Reduce internal building heat loads:

- Use high-efficiency lighting and equipment that minimize heat production.
- Use natural daylighting to reduce the demand for light from electric sources. (See pages 139–155 for more information.)
- In buildings dominated by heat transfer through the building skin, design and detail the building enclosure to minimize heat gains and uncontrolled air leakage.

Mitigate very dry or very humid air:

- In dry climates, take advantage of natural or human-made water features to raise the relative humidity.
- In humid climates, consider raising the building to avoid the most humid air close to the ground.
- In humid climates, avoid increasing humidity with water features or extensive vegetated areas.

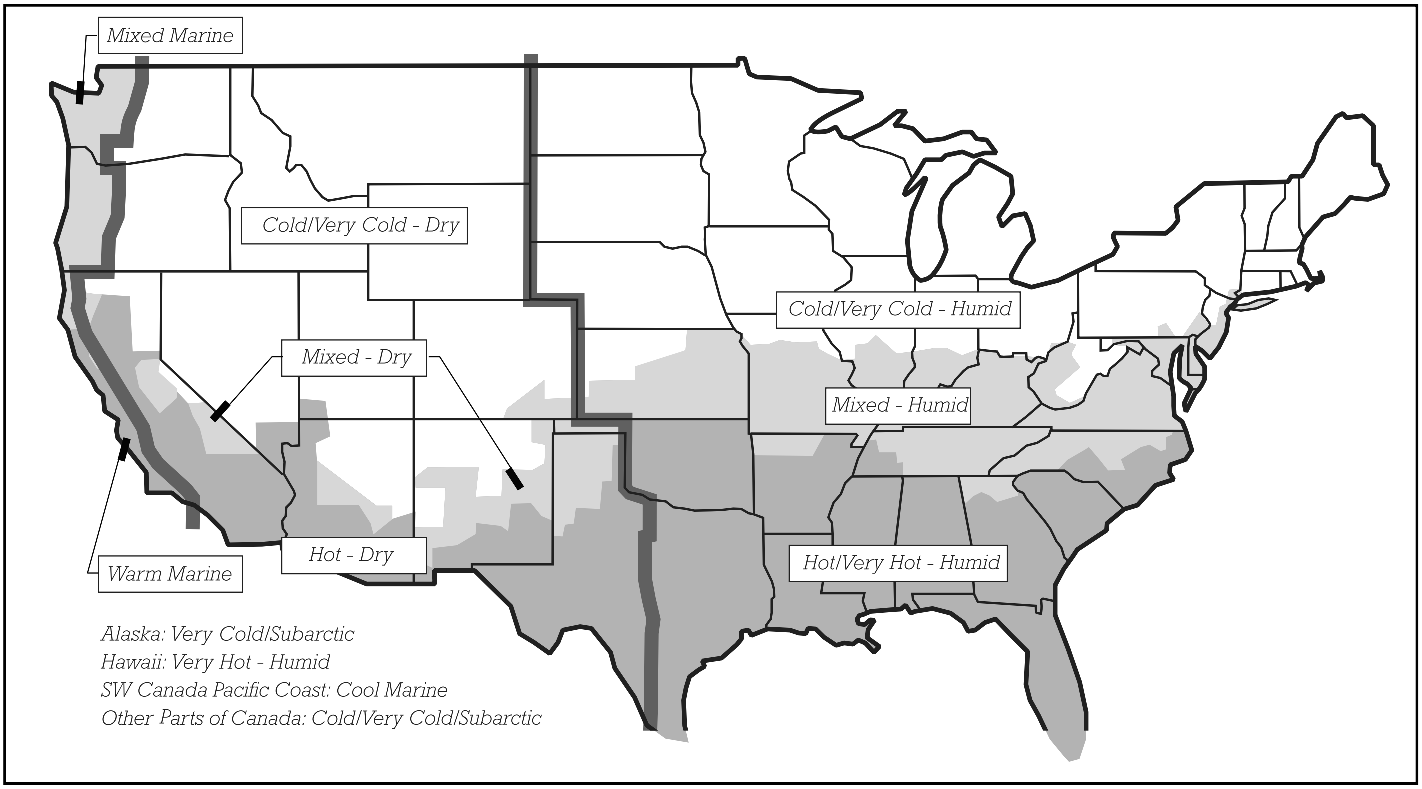
The successful performance of passive systems is dependent on the intimate interaction of the building with its environment. As your design work progresses, be sure to study further and analyze in greater detail the preliminary designs arrived at with the aid of this book.

# SELECTING PASSIVE HEATING AND COOLING SYSTEMS

The choice of suitable passive heating and cooling systems depends on the climate in which the building is located. Extremes of temperature and humidity define the conditions under which a building must remain comfortable to its occupants. Climatic conditions also define the resources available to the passive systems designer. For example, in a hot, dry climate with large temperature swings from day to night, cool nighttime air can be circulated through the building to extract heat generated during the day. Or, in a hot location with reliable prevailing winds, comfortable interior conditions may be maintained with cross ventilation through the building during daytime work hours.

The *Climate Zones* map on this page identifies major climate regions in the continental United States and other parts of North America. Note how the 48-state region is generally divided into humidity zones from west to east—*Marine*, *Dry*, and *Humid*—and temperature zones from north to south—*Cold*, *Mixed*, and *Hot*. Use this map to identify the climate zone in which your building is located.

Next, use the table labeled *Passive Heating and Cooling Systems* to identify strategies best suited to your project's climate. In cold climates, passive heating should be the primary design consideration, and in hot climates, passive cooling. Systems meeting these criteria are marked as *Most Suitable* in the table. For example, in a cold-dry climate, winter heating should be the primary concern, and solar heating is indicated. In hot climates, appropriate cooling strategies are identified this same way, and in mixed-temperature climates, both appropriate heating and cooling strategies are indicated. To learn more about these systems, see the pages referenced in the table.



**CLIMATE ZONES**

Other systems are marked as *Suitability Varies*. These may be considered for off-peak season conditioning, such as summer cooling in a primarily cold climate or winter heating in a primarily hot climate. In some cases, the appropriateness of these systems may also depend on more detailed climate specifics. See the chart below and the following pages.

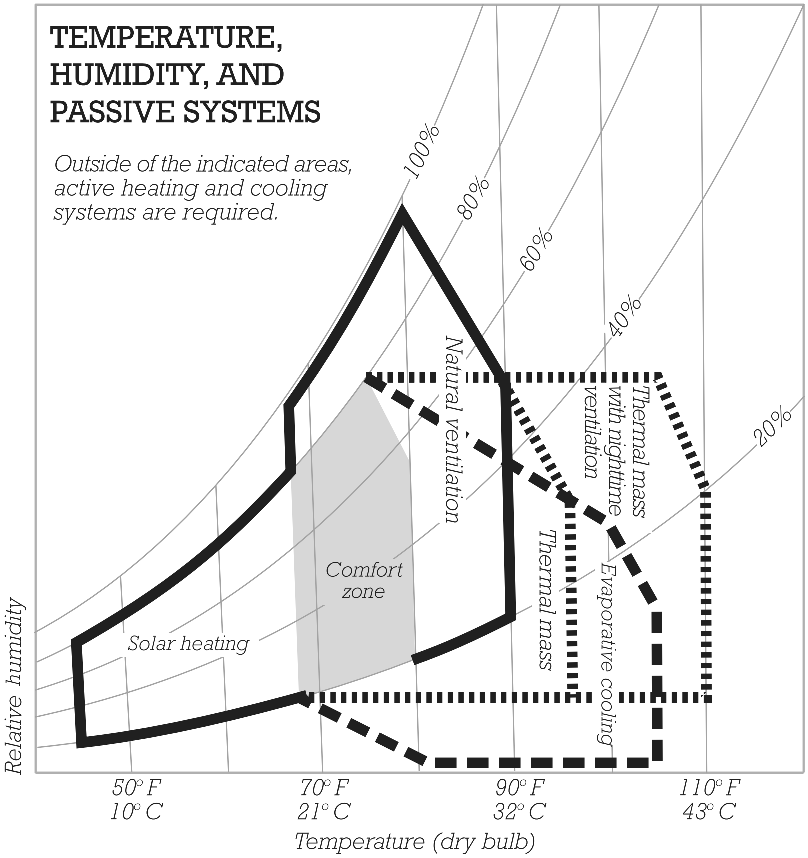
**PASSIVE HEATING AND COOLING SYSTEMS**

| | **HEATING** | **COOLING** | | | | |
|---|---|---|---|---|---|---|
| | **pages 222–224** | **pages 225–227** | **pages 225–227** | **pages 228–230** | **pages 228–230** | **pages 231–232** |
| **CLIMATE ZONE** | **Solar Heating** | **Cross Ventilation** | **Stack Ventilation** | **Thermal Mass** | **Thermal Mass with Nighttime Ventilation** | **Evaporative Cooling** |
| Cold-Humid | ● | ○ | ○ | | | |
| Cold-Dry | ● | ○ | ○ | ○ | | ○ |
| Mixed-Humid | ● | ● | ● | | | |
| Mixed-Dry | ● | ● | ● | ● | ○ | ○ |
| Mixed-Marine | ● | ● | ● | ○ | | |
| Hot-Humid | ○ | ● | ● | | | |
| Hot-Dry | ○ | ● | ● | ● | ● | ● |
| Warm-Marine | ○ | ● | ● | ○ | | |

● Most suitable
○ Suitability varies (see text)

# SELECTING PASSIVE HEATING AND COOLING SYSTEMS

Where more detailed ambient temperature and humidity data are available, use the chart at right to identify the systems most appropriate to your project. As project conditions approach or fall beyond the limits of the ranges indicated, active heating and cooling systems will be required. However, even when active systems are used, passive systems can in many instances still make a significant contribution to the cooling or heating requirements of a building and to a partial reduction in the building's reliance on fossil fuels or electricity.



***(Based on B. Stein et al., 2006.)***

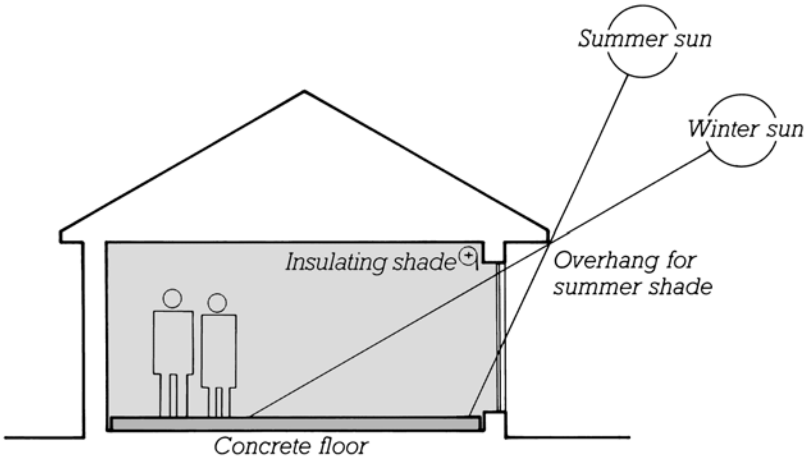
# PASSIVE SOLAR HEATING

## Description

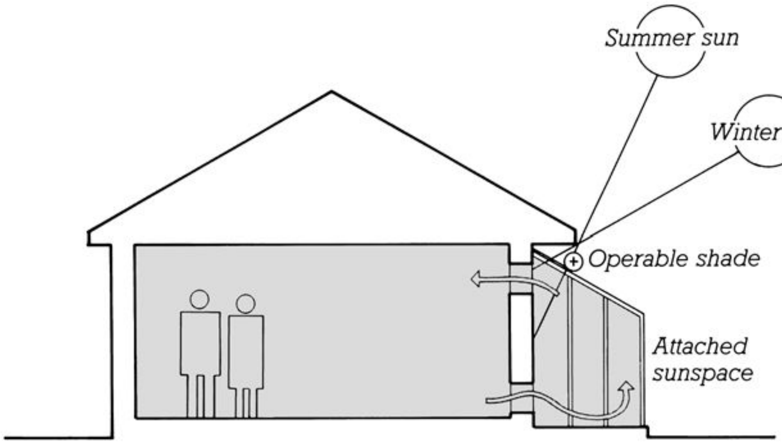
The interior space of the building acts as a solar collector, receiving sunlight directly through large south-facing windows and storing excess heat in thermal mass materials such as concrete, masonry, adobe, rammed earth, water, or phase-change salts. During sunless periods, a comfortable temperature is maintained as stored heat is released back into the space. Roof overhangs or exterior shading devices are configured to block out high summer sun when heat gain is not desirable. In colder climates, insulating shutters or curtains and high-performance glazing materials should be used to reduce heat losses through the large glass areas during cloudy days and nights.

## Typical Applications

Passive solar heating is suitable for small buildings in which heat loss through the building skin is the predominant winter design condition. This includes dwellings, schools, offices, and other low-rise buildings not dominated by internal heat gains.



**DIRECT GAIN PASSIVE SOLAR HEATING**



**ATTACHED SUNSPACE PASSIVE SOLAR HEATING**

## Advantages

Passive solar heating has no operational costs, consumes no energy, requires little or no maintenance, and can be aesthetically satisfying.

## Disadvantages

Except in mild climates, a backup heating system must be provided to heat the building during long sunless periods. Relatively large swings in interior temperature must be expected. Building occupants may be required to perform daily control duties such as opening and closing insulating shutters or curtains. The architecture of solar-heated buildings is strongly influenced by the need to orient and configure the building for optimum solar collection. Where floors, walls, or ceilings are used as thermal mass, these surfaces must not be covered with carpets, wall hangings, or other materials that thermally uncouple the mass from the interior. Cooling and humidity control must be accomplished with separate systems.

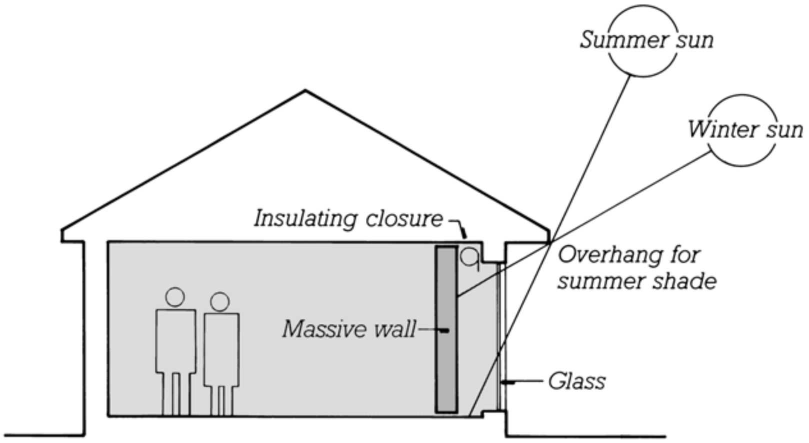
## Variations

**1.** In *direct gain solar heating*, sunlight enters south-facing windows, warming the interior directly. Thermal mass materials are located within the heated spaces. For maximum effectiveness, these materials should be situated in the path of direct sunlight. Direct gain solar heating is a simple, enjoyable way of bringing heat into a building, one that places the occupants in an intimate relationship with the seasons and the weather. However, direct sunlight causes visual glare, and it fades and deteriorates interior materials. Heat loss through the large glass areas during nights and cloudy days may be considerable.

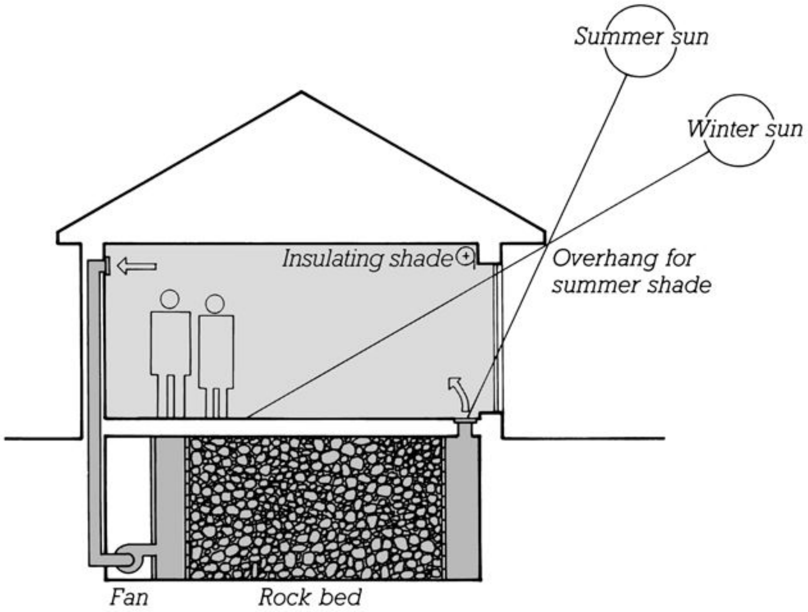
**2.** In *attached sunspace solar heating*, a greenhouse, glassy atrium, or glazed circulation corridor attached to the building collects solar heat by direct gain. Heated air is shared with adjacent spaces by means of natural convection or small, powered fans. Undesirable glare and fading are largely confined to the sunspace. The sunspace can be closed off during sunless periods and allowed to grow cold, reducing building heat losses during such periods. The sunspace will undergo large, often uncomfortable temperature fluctuations. Thermal mass walls and floors within the sunspace can, to some extent, moderate temperature swings. But unless additional active control mechanisms are provided, such spaces are typically unsuitable for growing plants or regular occupancy. Attached sunspace solar heating is generally the least efficient of the passive solar heating methods discussed in this section.

**3.** *Trombe wall solar heating* features thermal mass walls located immediately inside the windows that receive sunlight. The interior of the building is warmed by heat conducted through the walls, by allowing room air to convect between the wall and the glass, or both. Compared to direct gain solar heating, a Trombe wall system blocks a significant portion of the direct sunlight from the inhabited space, preventing glare and fading of materials. The wall occupies considerable space, however, and limits outdoor views.

**4.** *Fan-forced rock bed solar heating* is a hybrid of passive and active systems. Sunlight is brought directly into the inhabited spaces of the building. When the interior air temperature rises above the comfort level, thermostat-controlled fans draw the overheated air through a large container of stones, where the excess heat is absorbed. During sunless periods when the interior air temperature drops, the fan is actuated again to warm the room air by passing it through the heated stones. Compared to direct gain and Trombe wall solar heating, a fan-forced rock bed system gives better control of temperature and does not require the presence of massive materials within inhabited spaces. The rock bed is large and expensive to construct. Glare and fading are problems unless the system is coupled with an attached sunspace.

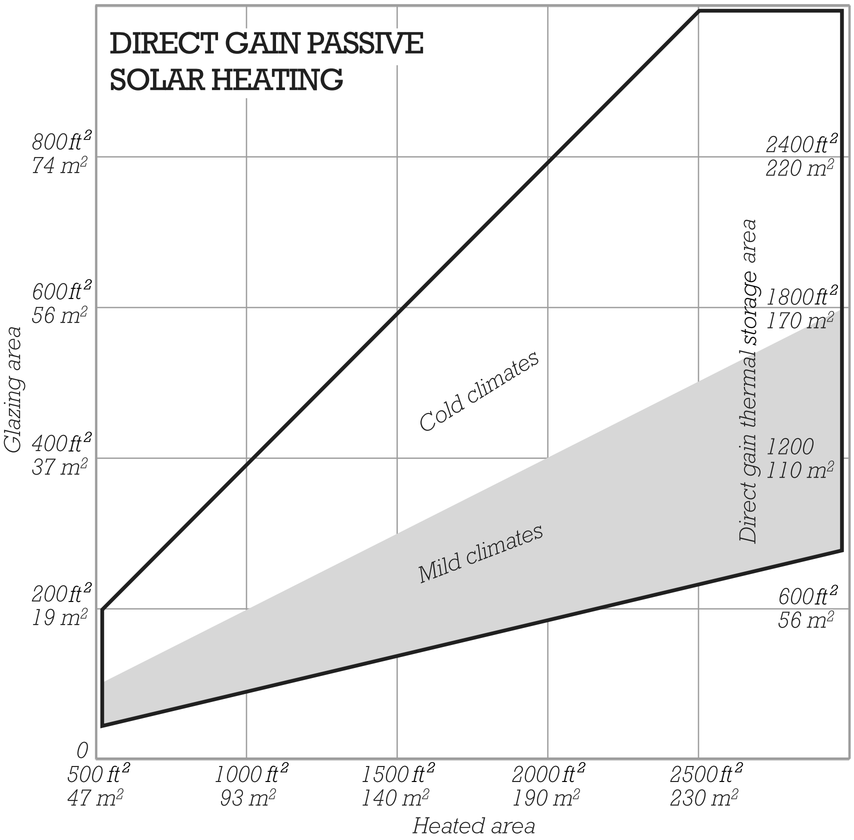


**TROMBE WALL PASSIVE SOLAR HEATING**



**FAN-FORCED ROCK BED PASSIVE SOLAR HEATING**

*(Continued on next page)*

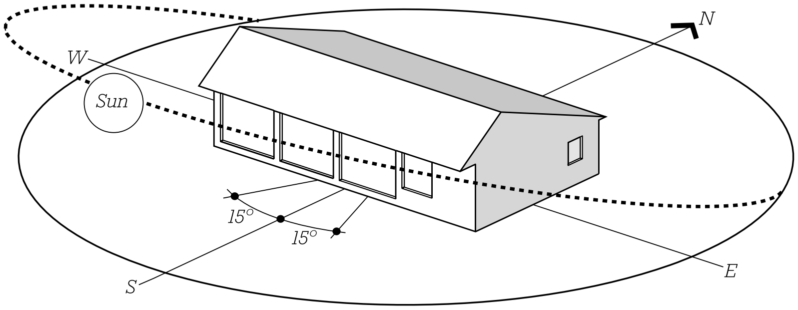


## Design

Passive solar buildings should be sited for maximum solar gain potential. Avoid locations shaded in the heating season by topography, vegetation, or human-made structures. Maximum solar gains are achieved when a building's collecting surfaces are oriented within 15 degrees of true south. However, even buildings oriented as much as 45 degrees away from south can still achieve some benefit. For more information on the path of the sun, see page 142.

Orient the long axis of the building east–west (in the northern hemisphere) and locate the most important interior spaces along the south side of the building. Locate utility rooms, bathrooms, and other secondary-use spaces along the north side of the building, where they can serve as heat loss buffers to this colder side. Use external shading devices to prevent undesirable gains from the high summer sun. Avoid unshaded large east- and west-facing glass areas that may make interior spaces prone to overheating.

For direct gain and Trombe wall systems, locate thermal mass surfaces in direct line of sight with occupants, allowing the benefit of thermal radiation from these surfaces.



## Sizing Passive Solar Heating Systems

Use the chart on this page to determine south-facing glazing and internal mass requirements for passive solar heating systems. Read higher in the chart ranges for buildings in areas with limited solar access; read lower in the ranges for well-insulated buildings. In most climates, a backup heating system must also be provided.

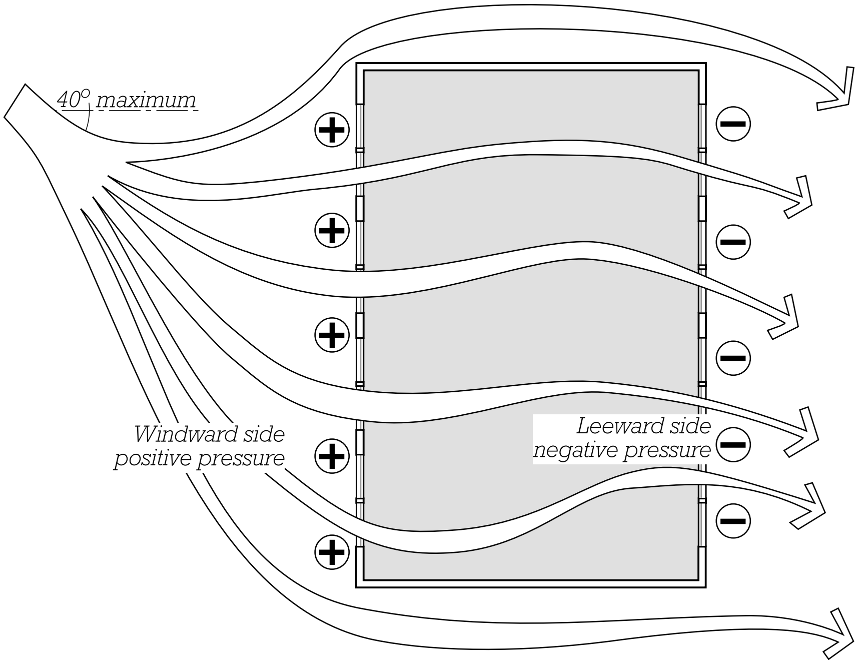
■ For direct gain systems, read the glazing area and thermal storage area directly from the chart. For designs relying on passive solar energy for a large portion of the building's total heating needs, increase the indicated thermal storage area by as much as a factor of 2. For water or phase-change salts, the indicated thermal mass area may be reduced by as much as a factor of 3.

■ For attached sunspace heating, read the glazing area directly from the chart. Thermal mass, if used, will be limited in area by the extent of the sunspace.

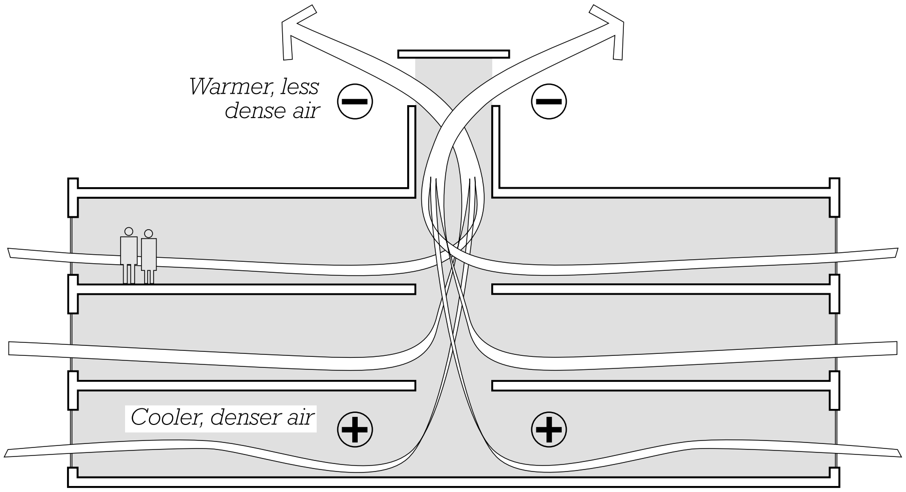
■ For Trombe wall heating, read the glazing area directly from the chart. For designs relying on passive solar energy for a large portion of the building's total heating needs, increase the recommended glazing area by as much as a factor of 1.5. The area of mass walls is equal to the glazing area. They are typically 6 to 16 in. (150 to 400 mm) thick and spaced 1 to 24 in. (25 to 300 mm) from the adjacent windows. Use a thinner wall where heating needs are more immediate during the day; use a thicker wall where heating needs are delayed until evening or night.

■ For fan-forced rock bed heating, read the glazing area directly from the chart. Provide 0.5–0.75 cu ft of rock storage per square foot of glazing (0.15–0.22 $m^3$ of rock per square meter of glazing). For example, with 400 sf (37 $m^2$) of south-facing glazing, provide 200–300 cu ft (5.6–8.1 $m^3$) of rock storage.

# NATURAL VENTILATION COOLING



**CROSS VENTILATION (PLAN VIEW)**



**STACK VENTILATION (SECTION VIEW)**

## Description

Outside air circulates through the building during occupied hours. Occupant comfort is improved by the direct cooling effect of the moving air. As air passes through the building, excess heat is flushed to the exterior.

## Typical Applications

Natural ventilation cooling is adaptable to most climate types where cooling is required. It is an especially good choice for humid climates where other passive cooling strategies are less effective. This type of cooling is best suited to small and medium-sized buildings. It is not frequently employed in tall buildings, where the large air pressure differentials that develop across the faces of such buildings make regulation of naturally driven airflows difficult.

## Advantages

Natural ventilation cooling is a passive strategy with no significant operational costs, energy consumption, or maintenance needs.

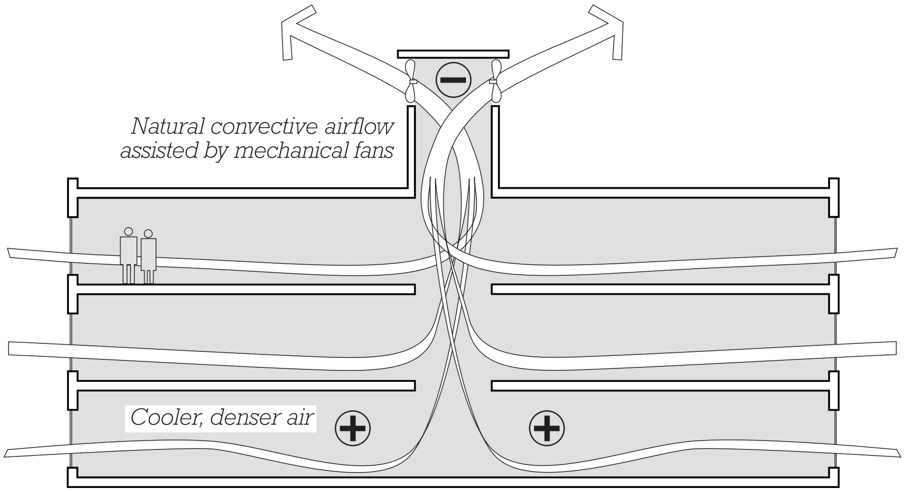
## Disadvantages

Natural ventilation strategies rely on large exterior openings, open floor plans, and, in some cases, interconnected floor levels. These may conflict with program requirements, visual or acoustic privacy needs, or fire-safety regulations requiring compartmentalization of spaces. Precise control of interior air temperature, humidity, and air pollutants is not possible. The necessary exterior openings may admit unwanted outside noise into the building.

## Variations

**1.** *Cross ventilation* relies on wind forces to move air through the building. Passage of the wind creates areas of higher and lower air pressure on different parts of the building exterior. With appropriately arranged exterior openings, these pressure differences can be exploited to move outside air through the interior. This strategy requires building locations exposed to reliable prevailing winds during the cooling season.

**2.** *Stack ventilation* relies on convective pressures (the natural buoyancy of warmer air compared to cooler air) to move air through the building. As interior air gains heat, it rises and then is exhausted from openings located high in the building, while cooler outside air is drawn in lower down. Stack ventilation is an effective alternative to cross ventilation where prevailing winds are weak or unpredictable. However, stack ventilation requires structures of sufficient height to produce the necessary convective forces.



MECHANICALLY ASSISTED NATURAL VENTILATION

**3.** *Mechanically assisted natural ventilation cooling* uses powered fans to increase airflows through the building when prevailing winds or stack pressures are insufficient to meet the air movement and cooling needs of the building's occupants.

## Design

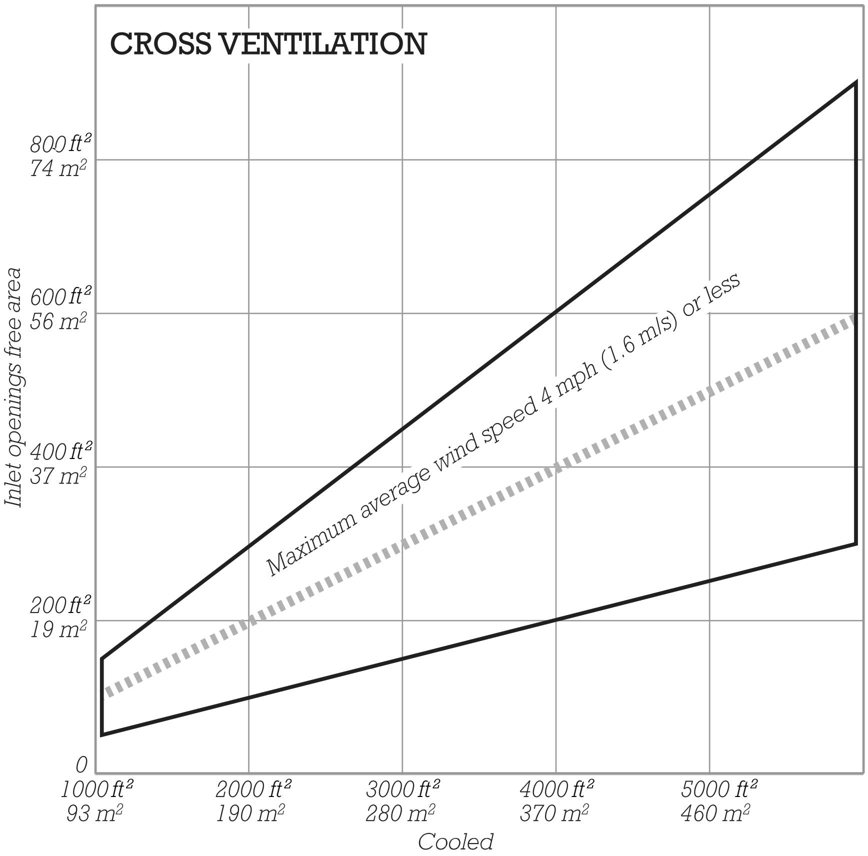
Cross ventilation cooling depends on the availability of consistent winds during the building's cooling season operating hours. Local wind data can be obtained from a variety of sources, including those listed in this book's bibliography. Such data, often obtained at airport or other open field locations, should be adjusted to reflect local site conditions. For example, average wind speeds in dense urban areas may be as much as one-half of those recorded for open areas. Wind shadows from adjacent structures, the channeling of wind in narrow valleys or urban canyons, the acceleration of wind over bodies of water, and other localized effects on wind speed and direction should also be considered.

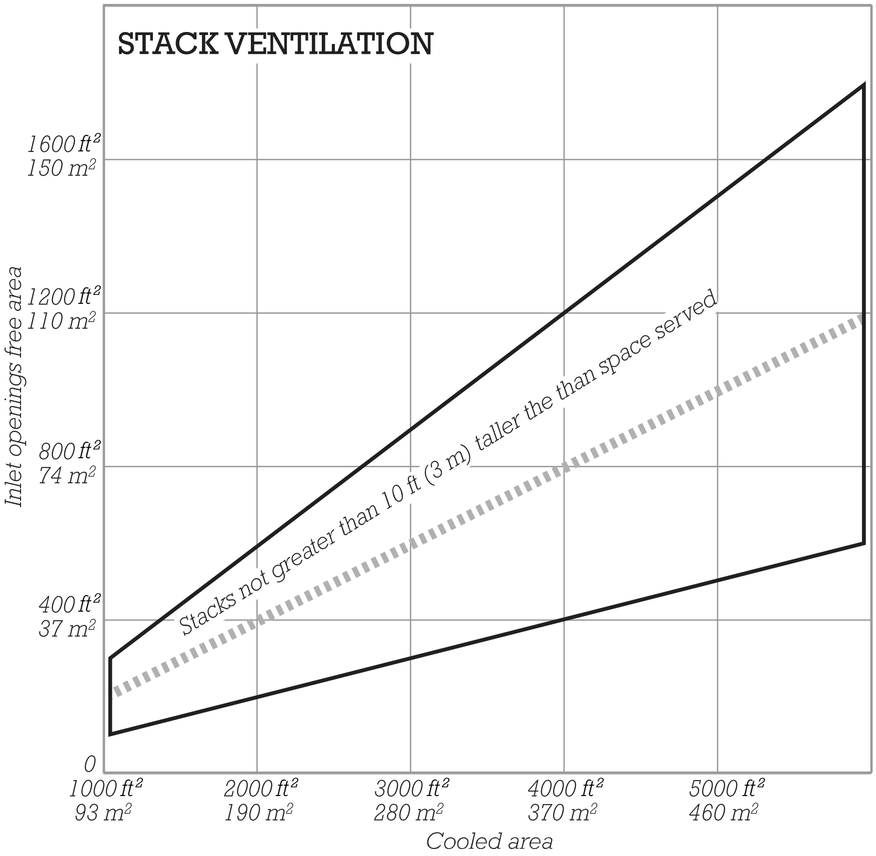
Cross ventilated buildings and their openings should be oriented to exploit the prevailing winds. For buildings rectangular in plan, the longer side should be oriented roughly perpendicular to the direction of the wind or at an angle of not more than 40 degrees from this direction. Exterior openings should be divided between areas of positive pressure (windward exposure) and negative pressure (leeward exposure). The combined area of the leeward openings should be at least as great as that of the windward openings. Where prevailing winds are reliable in strength but not direction, openings should be arranged in multiple orientations so that they work effectively with winds from any expected direction.

Stack ventilation depends on stack height to generate the convective pressures that move air through the building. Stack effectiveness can also be enhanced with wind-induced negative pressures at the top of the stack, by solar heating of the portion of the stack above the building (a solar chimney), or with the aid of powered fans. When a stack serves multiple floor levels, it should be at least one-third to one-half as tall as the height of the levels served so as to provide effective ventilation for the highest levels. Building orientation is generally not critical to successful stack ventilation, although care should be taken to ensure that where strong winds occur, they will not work at cross purposes to stack-induced pressures. The free area of the stack outlet openings and the stack itself should be at least as great as the area of the windows or other air inlet openings. Inlet openings and stacks should be arranged to balance airflow throughout ventilated areas and to avoid dead zones where air can stagnate.

Within any naturally ventilated building, air must be able to flow freely from inlet to outlet openings. Thus, the cross-sectional area of internal openings should be at least as great as the area of the exterior inlets, and these openings should be arranged to allow air to circulate throughout the areas to be cooled. Because circulation air gains heat as it moves through the building, occupants should be located close to air inlets where possible, and equipment or other sources of heat should be located close to outlets. Within individual spaces, locating air inlets low and outlets high can exploit convective effects to enhance air movement and maximize heat extraction from the space.

As with any type of passive cooling design, building heat gains from both internal and external sources should be minimized. Solar heating should be controlled with shading strategies and the choice of appropriate glazing materials. Internal heat gains should be minimized with the selection of efficient lighting devices and equipment. Daylighting strategies should be employed where possible.





## Sizing Natural Ventilation Systems

Use the top chart on this page to find the minimum total area of inlet openings for a cross-ventilated building. Read higher in the indicated areas for hotter climates, buildings with higher internal heat gains, or lower wind speeds. Read lower for cooler climates, buildings with lower internal heat gains, or higher wind speeds.

- For building locations with average wind speeds of 4 mph (1.6 m/s) or less, read only above the dashed line indicated. For locations with faster winds, read in all areas indicated.
- For openings with insect screening, double the indicated free area. For louvers or other partial opening obstructions, adjust the indicated area appropriately.
- The combined area of outlet openings should be equal to or greater than the combined area of inlet openings.

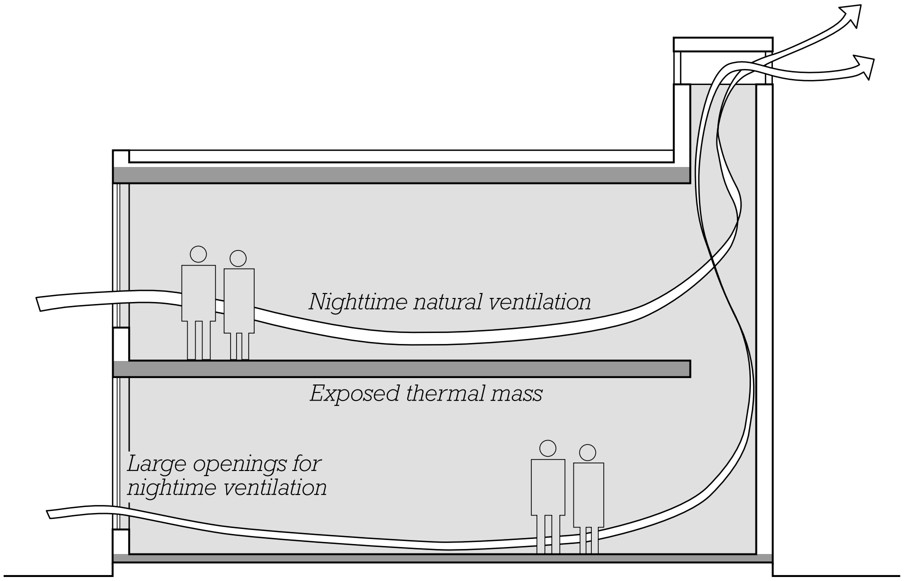
Use the bottom chart on this page to find the combined minimum area of inlet openings for a stack-ventilated building. Read higher in the chart for hotter climates, buildings with higher internal heat gains, or shorter stacks. Read lower for cooler climates, buildings with lower internal heat gains, or taller stacks.

- For openings with insect screening, double the indicated area.
- For stacks not more than 10 ft (3 m) tall, read only above the dashed line indicated. For taller stacks, read in all areas indicated.
- The combined cross-sectional area of stacks should be equal to or greater than the combined area of inlet openings serving the same area.

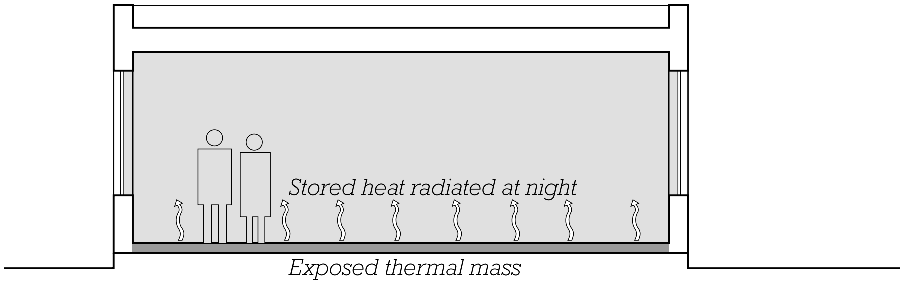
# THERMAL MASS COOLING

## Description

During the day, thermal mass materials within the building absorb heat and moderate rising temperatures. During the night, the building is ventilated with cooler outside air, extracting the stored heat from the mass and flushing it to the exterior. Heavyweight structural systems such as concrete, masonry, rammed earth, or adobe serve as thermal mass.



THERMAL MASS WITH NIGHTTIME VENTILATION



THERMAL MASS WITHOUT NIGHTTIME VENTILATION

## Typical Applications

Thermal mass cooling is an effective strategy where outdoor temperature swings are high—20°F (11°C) or more—on an average daily basis. The most favorable conditions for thermal mass cooling occur in dry climates, such as in any of the U.S. dry climate zones shown on the map on p. 219. However, outside of coastal areas, minimally acceptable conditions for this strategy can be found throughout much of the continental United States.

During the day, when outside air temperatures are higher than those inside the building, all or most windows remain closed. Indoor air quality is maintained by some combination of mechanical ventilation and/or controlled use of operable openings. During the cooler nights, windows are opened and natural ventilation is used to circulate large volumes of air through the building, thereby removing the stored heat. Alternatively, nighttime ventilation can be provided mechanically, making thermal mass cooling applicable to a greater variety of building sizes and configurations than those adaptable to natural ventilation.

## Advantages

Thermal mass cooling with nighttime natural ventilation is a passive strategy without significant operational costs, energy consumption, or maintenance needs. When ventilation is provided mechanically, energy costs are still low in comparison to those for conventional active building cooling systems. Where thermal mass cooling on its own cannot maintain comfortable interior temperatures, it can also work in conjunction with active systems.

The same thermal mass used for summer cooling can be used for passive solar heating in climates where both strategies are appropriate.

## Disadvantages

Thermal mass surfaces cannot be covered with carpeting, acoustic panels, or other materials that thermally insulate the mass from the interior air. Where nighttime ventilation is provided by natural means, humidity and air pollutants may be difficult to control, and the necessarily large exterior openings may create building security or acoustic concerns. Natural ventilation strategies also rely on open floor plans and interconnected spaces that may conflict with programmatic requirements or regulations requiring compartmentalization of space for fire safety.

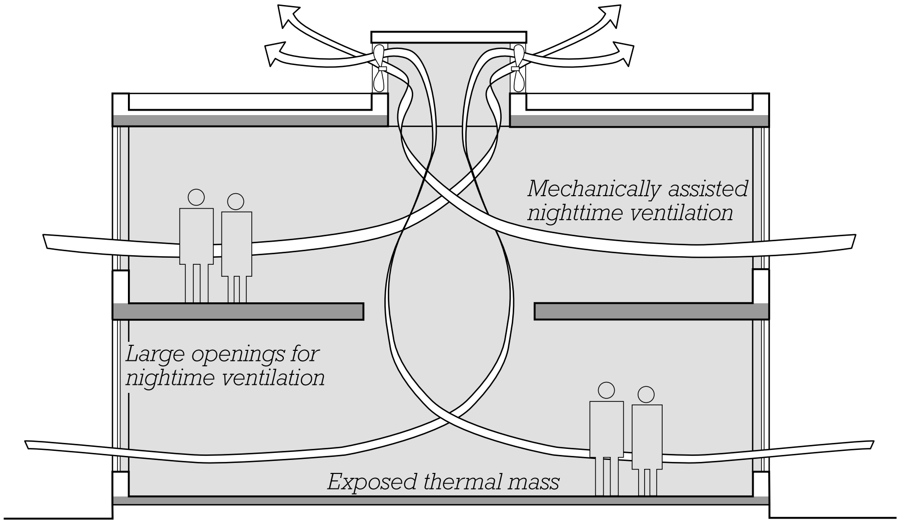
## Variations

**1.** In *thermal mass with natural nighttime ventilation*, heat stored during the day by interior mass is flushed from the building at night using natural ventilation strategies. Stack ventilation, which is not dependent on nighttime winds, may be preferred over cross ventilation. Open floor plans are required to ensure thorough flushing of the thermal mass surfaces. For more information on design for natural ventilation, see pages 225–227.

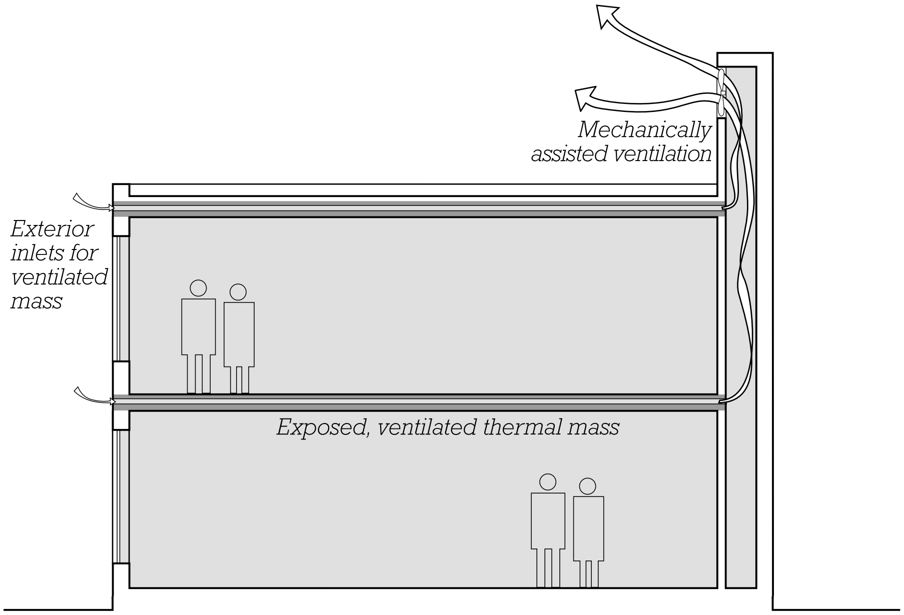
**2.** In *thermal mass without nighttime ventilation,* heat stored by building mass during hot days is released directly back into interior spaces during cooler nights. This strategy is most suitable for relatively small buildings located in cooler climates. The heat accumulated during the day either serves to keep the building comfortably warm during the night or is lost through the building skin without the aid of nighttime ventilation. See the chart on page 220 for conditions suitable to this strategy.

**3.** *Thermal mass with mechanically assisted nighttime ventilation* works similarly to variation 1. But the reliance on mechanical systems rather than natural ventilation to move nighttime air through the building makes this variation practical for a greater variety of building sizes and configurations.

**4.** *Thermal ventilated mass* is another mechanically assisted variation in which the thermal mass components are hollow, and nighttime air is drawn by fans directly through the mass components themselves rather than through the interior spaces of the building. Hollow core concrete planks (see pages 132–133) are one example of a structural component adaptable to this application. This variation reduces the need for open floor plans and large, operable exterior openings.



**THERMAL MASS WITH MECHANICALLY ASSISTED NIGHTTIME VENTILATION**



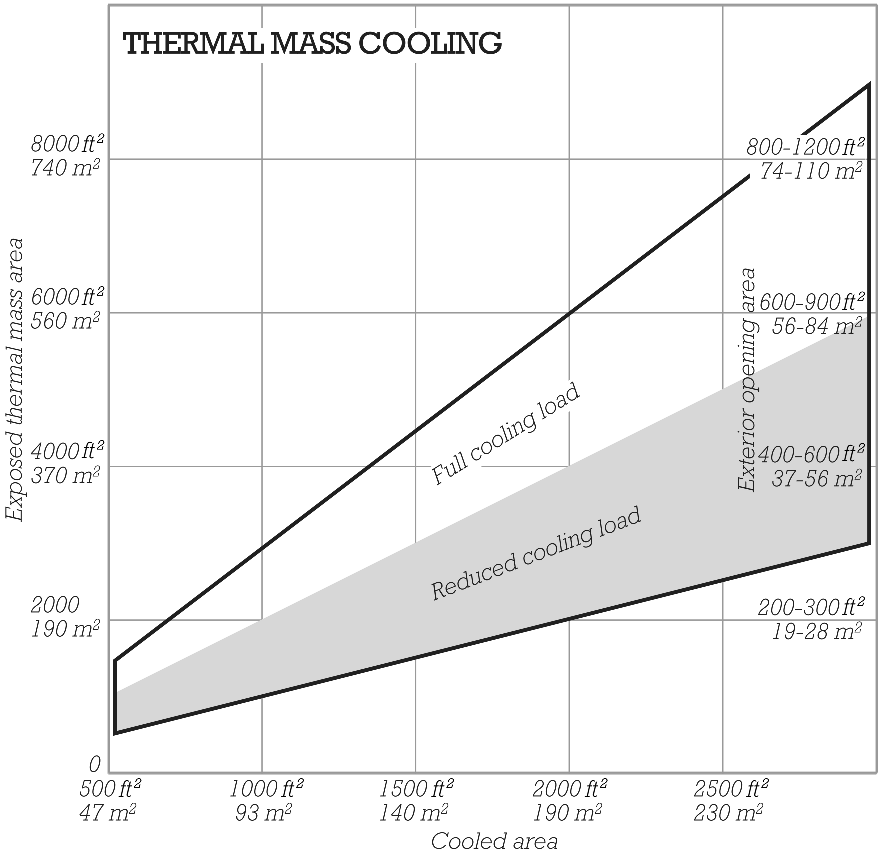
**THERMAL VENTILATED MASS**

## Design

The thermal mass surfaces must be located within the occupied areas of the building and must be situated in the direct path of the nighttime ventilation airflow. Where possible, these surfaces should be in the direct line of sight of building occupants so that occupants may also benefit from radiant cooling effects. Building thermal insulation must be positioned to the exterior side of the thermal mass. For buildings constructed of lighter-weight structural systems, special wallboard or other materials formulated with encapsulated phase change materials may provide the needed thermal capacity.

For designs that rely on flushing of nighttime air through interior spaces (variations 1 and 3 above), these spaces must be sufficiently open and interconnected to permit unimpeded airflow. Where nighttime ventilation is provided by natural means, the building design guidelines for natural ventilation provided on pages 225–227 should be followed. Note however, that these two strategies, natural ventilation cooling (which occurs during the day) and thermal mass cooling with nighttime ventilation, cannot be used in the same building.

As with any type of passive cooling design, building heat gains from both internal and external sources should be minimized. Solar heating should be controlled with shading strategies and the choice of appropriate glazing materials. Internal heat gains should be minimized with the selection of efficient lighting devices and equipment. Daylighting strategies should be employed where possible.



## Sizing Thermal Mass Cooling Systems

Use the chart on this page to determine the required areas for internal thermal mass and exterior openings for thermal mass cooling designs. Read higher in the indicated areas for hotter climates or for buildings with higher internal heat gains. Read lower in the chart for cooler climates or for buildings with lower internal heat gains.

- For thermal mass with natural nighttime ventilation, read exposed thermal mass and exterior opening areas from within the *Full cooling load* chart area.
- For thermal mass without nighttime ventilation, read exposed thermal mass areas anywhere within either the *Full* or *Reduced cooling load* chart areas.
- For thermal mass with mechanically assisted nighttime ventilation, read exposed thermal mass areas from the *Full cooling load* chart area. Reduce the indicated exterior opening area by one-half.
- For thermal ventilated mass, read exposed thermal mass from the *Full cooling load* chart area.

# EVAPORATIVE COOLING

## Description

Hot, dry outside air passes through wetted pads or misted water in cooling towers located above the occupied portions of a building. As the water evaporates, the air is cooled and its relative humidity rises. This cooler, moister, and more comfortable air then descends and passes through the building interior.

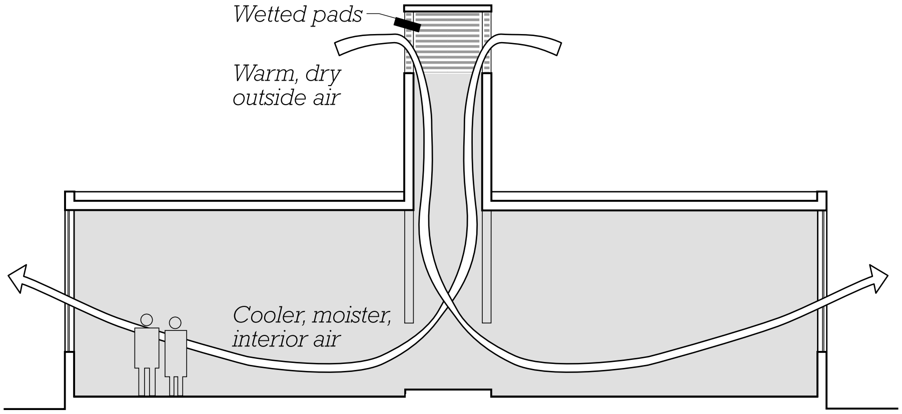
## Typical Applications

Evaporative cooling lowers the temperature of air and raises its moisture content. It is most appropriate for hot, dry climates (see the map on page 219) where adding moisture to air does not decrease comfort. Passive evaporative cooling relies on natural ventilation to distribute the conditioned air through the building, making it most suitable for small and medium-sized buildings.

Appropriate conditions for evaporative cooling are represented graphically on the *Temperature, Humidity, and Passive Systems* chart on page 221. Where additional local climate data are available, consider passive evaporative cooling where average exterior *wet bulb* temperatures do not exceed 68 to 70°F (20 to 21°C) at the hottest time of the year.

## Advantages

Evaporative cooling does not depend on the wind, making it a possible alternative where natural ventilation is not practical. Evaporative cooling systems consume far less energy than conventional refrigeration cycle equipment, requiring only small amounts of power to supply water to the tower. Evaporative coolers do not use environmentally hazardous refrigerants.



**EVAPORATIVE COOLING**

## Disadvantages

Evaporative cooling depends on the cooling effect of water evaporation. It is not effective in humid climates, where adding water to the air would serve mainly to increase the relative humidity that is already uncomfortably high but do little to lower air temperature. Evaporative cooling systems consume water. They may not be appropriate for arid areas where water supplies are restricted. The very damp portions of the system may introduce odors into the supply air stream and have the potential to foster biological growth. Periodic inspection and cleaning may be required.

## Variations

**1.** *Passive evaporative cool towers* extend above the roof level of the building. Outside air is drawn into the top of the towers, where it passes through pads kept continuously damp or through a continuous water mist. As the air is cooled and humidified by water evaporation, it becomes more dense and descends into the building. No fans are required to move the air.

**2.** *Small mechanical evaporative coolers* are packaged units that use powered fans rather than natural convective forces to move evaporative cooled air through the units and into the building. They are suitable for small buildings. For more information on coolers of this type see page 249.

**3.** *Larger mechanical evaporative coolers* are more sophisticated packaged units that can be incorporated into conventional ducted HVAC systems. In appropriate climates, these units can replace or supplement refrigeration-based cooling equipment, reducing cooling costs and energy consumption. *Indirect* mechanical evaporative coolers use a heat exchanger to cool interior air without introducing additional moisture, expanding somewhat the range of climate conditions under which these units can be used. For more information on the use of packaged cooling equipment in larger buildings, see pages 186–187.

## Design

A natural downdraft is created in the cool tower as warm outside air enters the tower, is cooled and humidified, and increases in density. As this more comfortable air descends into the building, warmed interior air is displaced and exhausted through remote windows or other openings. In fact, cool towers function essentially as the reverse of stack ventilation, and these towers are sometimes called *reverse chimneys*.

Passive evaporative cooling relies on natural ventilation to distribute conditioned air throughout the building. Wind or stack pressures are not required, as the pressure to move building air comes from the descending heavier air in the tower itself. The building interior must be sufficiently open to allow efficient movement of air, and exterior openings of sufficient size and appropriate distribution must be provided to act as air outlets. Cool towers can also be combined with stack ventilation, with the cool towers acting as air inlets and other ventilation stacks acting as outlets. Use the guidelines on pages 225–227 for the design of natural ventilation aspects of the system.

As with any type of passive cooling design, building heat gains from both internal and external sources should be minimized. Solar heating should be controlled with shading strategies and the choice of appropriate glazing materials. Internal heat gains should be minimized with the selection of efficient lighting devices and equipment. Daylighting strategies should be employed where possible.

## SIZING COOL TOWERS

The required height of the cool tower and the area of cooling media (wetted pads) depend on the exterior temperature and humidity, the internal cooling load, and the building area to be served. Use the table on this page as a guide for preliminary cool tower selection. Use taller, larger-dimension towers in hotter, more humid climates and in buildings with higher internal cooling loads. Use smaller, shorter towers where requirements are less severe.

In the following table, the *Smaller-Dimension Cool Tower* is assumed to have a cooling media area of 32 sq ft (3.0 m$^2$) and the *Larger-Dimension Cool Tower* to have a cooling media area of 48 sq ft (4.5 m$^2$). Practical dimensions for the tower itself range from 10 to 40 ft (3.0 to 12 m) in height and approximately 5 to 12 ft (1500 to 3600 mm) on each side. Tower height is measured from where air enters the tower to where it exits.

**TYPICAL COOL TOWER SIZES**

| | | | **BUILDINGS WITH LOW COOLING LOAD** | | **BUILDINGS WITH MEDIUM COOLING LOAD** | |
|---|---|---|---|---|---|---|
| **Exterior Temperature** | **Exterior Relative Humidity** | **Building Area to Be Cooled** | **Height of Smaller-Dimension Cool Tower** | **Height of Larger-Dimension Cool Tower** | **Height of Smaller-Dimension Cool Tower** | **Height of Larger-Dimension Cool Tower** |
| 90°F<br>(32°C) | 23% | 1500 ft$^2$<br>(140 m$^2$) | 15'<br>(4.6 m) | | 20'<br>(6.1 m) | |
| 90°F<br>(32°C) | 18% | 1500 ft$^2$<br>(140 m$^2$) | 10'<br>(3 m) | | 15'<br>(4.6 m) | |
| 105°F<br>(41°C) | 15% | 1500 ft$^2$<br>(140 m$^2$) | 10'<br>(3 m) | | 15'<br>(4.6 m) | |
| 90°F<br>(32°C) | 23% | 3000 ft$^2$<br>(280 m$^2$) | | 20'<br>(6.1 m) | | 35'<br>(11 m) |
| 90°F<br>(32°C) | 18% | 3000 ft$^2$<br>(280 m$^2$) | 40'<br>(12 m) | | | 30'<br>(9 m) |
| 105°F<br>(41°C) | 15% | 3000 ft$^2$<br>(280 m$^2$) | 35'<br>(11 m) | | | 25'<br>(7.6 m) |

# 4

# MECHANICAL AND ELECTRICAL SYSTEMS FOR SMALL BUILDINGS

***This chapter will help you select a heating and cooling system for the preliminary design of a small building. It also summarizes typical plumbing and electrical systems for small buildings.***

# DESIGNING SPACES FOR MECHANICAL AND ELECTRICAL SERVICES FOR SMALL BUILDINGS

Small buildings are defined for purposes of this section as those that use residential-scale mechanical and electrical systems. This category may include small educational, commercial, retail, industrial, and institutional buildings as well as houses, townhouses, and small apartment buildings.

Heating and cooling loads in small buildings are usually dominated by heat gains and losses through the skin of the building. In many small buildings, mechanical fresh air ventilation is not an issue because of the low density of occupancy and the ability of operable windows and normal air leakage through the skin of the building to provide adequate ventilation. Most of the distribution lines for the mechanical and electrical systems in small buildings can be concealed within the hollow cavities that are a normal part of the floor, wall, and ceiling structures. A basement, crawlspace, or attic is often available as a location for the major mechanical equipment and larger horizontal distribution lines. There is an enormous variety of heating and cooling systems from which the designer may choose. This section summarizes the choices of heating and cooling systems and the typical plumbing and electrical systems. Approximate dimensions of the components of the various systems are also given.

# DESIGN CRITERIA FOR THE SELECTION OF HEATING AND COOLING SYSTEMS FOR SMALL BUILDINGS

| | |
|---|---|
| *Decide first if the building needs a heating system, cooling system, or both heating and cooling:* | Some systems are capable of heating only, such as:<br>Hydronic heating (pages 246–247)<br>Active solar heating (page 248)<br>Electric convectors and heaters (pages 251–252)<br>Radiant panel heating (page 253)<br>Wall furnace and direct-vent space heaters (page 254)<br>Heating stoves (page 255)<br>Passive solar heating (pages 222–224)<br>Some systems are capable of both heating and cooling the building, such as:<br>Forced air (pages 243–245)<br>Heat pump (pages 178, 244–245)<br>Packaged terminal units or through-the-wall units (page 250)<br>Single-packaged and split-packaged systems (pages 186–187)<br>Some systems are capable of cooling only, such as:<br>Packaged evaporative air (page 249)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Passive evaporative cooling (pages 231–232) |
| *If you wish to minimize the first cost of the system:* | Choose systems that do not require the installation of extensive piping or ductwork, such as:<br>Packaged evaporative cooler (page 249)<br>Packaged terminal units or through-the-wall units (page 250)<br>Electric convectors or fan-forced heaters (pages 251–252)<br>Wall furnace and direct-vent space heaters (page 254)<br>Heating stoves (page 255)<br>or consider an appropriate passive heating or cooling system, such as:<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Passive evaporative cooling (pages 231–232) |
| *If you wish to minimize operating costs and energy consumption in cold climates:* | Choose systems that burn fossil fuels efficiently or those that burn locally available, low-cost fuels, such as:<br>Forced air (pages 243–245)<br>Hydronic heating (pages 246–247)<br>Active solar heating (page 248)<br>Heating stoves (page 255)<br>or consider a passive heating system:<br>Passive solar heating (pages 222–224) |

# DESIGN CRITERIA FOR THE SELECTION OF HEATING AND COOLING SYSTEMS FOR SMALL BUILDINGS

| | |
|---|---|
| *If you wish to minimize operating costs and energy consumpton in moderate climates:* | Choose systems that utilize ambient energy sources, such as:<br>Heat pump systems (pages 178, 244–245)<br>Active solar heating (page 248)<br>Heating stoves (page 255)<br>Packaged evaporative cooler (page 249)<br>or consider a passive system:<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Passive evaporative cooling (pages 231–232) |
| *If you wish to maximize control of air quality and air velocity for maximum comfort:* | Choose a system that filters and moves the air mechanically, namely:<br>Forced air (pages 243–245) |
| *If you wish to maximize individual control over temperature:* | Choose systems that offer separate thermostats in a number of rooms or zones, such as:<br>Hydronic heating (pages 246–247)<br>Packaged terminal units or through-the-wall units (page 250)<br>Electric convectors or fan-forced heaters (pages 251–252) |
| *If you wish to minimize the noise created by the heating and cooling system:* | Choose systems in which motors, pumps, and fans are distant from the occupied space, such as:<br>Forced air (pages 243–245)<br>Hydronic heating (pages 246–247)<br>Electric convectors and radiant heating (pages 251–253)<br>or consider a passive system:<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Passive evaporative cooling (pages 231–232) |
| *If you wish to minimize the visual obtrusiveness of the heating and cooling system:* | Choose systems that place as little hardware as possible in the occupied spaces, such as:<br>Forced air (pages 243–245)<br>Radiant heating (page 253)<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Passive evaporative cooling (pages 231–232) |

# DESIGN CRITERIA FOR THE SELECTION OF HEATING AND COOLING SYSTEMS FOR SMALL BUILDINGS

| | |
|---|---|
| *If you wish to maximize the inhabitants' enjoyment of the changing weather and seasons:* | Choose systems that change prominently with the seasons, such as:<br>Heating stoves (page 255)<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Passive evaporative cooling (pages 231–232) |
| *If you wish to minimize the amount of floor space occupied by heating and cooling equipment:* | Choose systems that do not occupy floor space, such as:<br>Packaged evaporative cooler (page 249)<br>Packaged terminal units or through-the-wall units (page 250)<br>Electric fan-forced heaters (page 252)<br>Electric radiant heating (page 253)<br>Wall furnace and direct-vent space heaters (page 254)<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Passive evaporative cooling (pages 231–232) |
| *If you wish to minimize system maintenance:* | Choose systems with few or no moving parts, such as:<br>Forced air (pages 243–245)<br>Hydronic heating (pages 246–247)<br>Electric convectors (page 251)<br>Electric radiant heating (page 253)<br>Wall furnace and direct-vent space heaters (page 254)<br>Passive solar heating (pages 222–224)<br>Natural ventilation cooling (pages 225–227)<br>Thermal mass cooling (pages 228–230)<br>Passive evaporative cooling (pages 231–232) |
| *If you wish to avoid having a chimney in the building:* | Choose systems that do not burn fuel in the building, such as:<br>Heat pump furnace (pages 244–245)<br>Active solar heating (page 248)<br>Single-packaged and split-packaged systems (pages 186–187)<br>Packaged terminal units or through-the-wall units (page 250)<br>All types of electric heat (pages 251-253)<br>Wall furnace and direct-vent space heaters (page 254)<br>Passive solar heating (pages 222–224)<br>With some fuel-burning systems, high-efficiency furnaces may be available that can be ventilated through a wall and do not require a chimney. Consult manufacturers' literature for more detailed information. |
| *If you wish to maximize the speed of construction:* | Choose systems that involve as few components and as few trades as possible, such as:<br>Packaged terminal and through-the-wall units (page 250)<br>All types of electric heat (pages 251–253) |

# HEATING AND COOLING SYSTEMS FOR SMALL BUILDINGS: SUMMARY CHART

| **GIVE SPECIAL CONSIDERATION TO THE SYSTEMS INDICATED IF YOU WITH TO:** | **Forced Air (page 243)** | **Heat Pump Furnace (page 244)** | **Hydronic Heating (page 246)** | **Active Solar Heating (page 248)** | **Packaged Evaporative Cooler (page 249)** | **Packaged Terminal or Through-the-Wall Units (page 250)** |
|---|---|---|---|---|---|---|
| Provide only heating or cooling, or both | Heating and cooling | Heating and cooling | Heating only | Heating only | Cooling only | Heating and cooling |
| Minimize first cost | | | | | ● | ● |
| Minimize operating costs and energy consumption in cold climates | ● | | ● | ● | | |
| Minimize operating costs and energy consumption in moderate climates | | ● | | ● | ● | |
| Maximize control of air velocity and air quality | ● | ● | | | | |
| Maximize individual control over temperature | | | ● | | | ● |
| Minimize system noise | ● | ● | ● | ● | | |
| Minimize visual obtrusiveness | ● | ● | | | | |
| Maximize enjoyment of the seasons | | | | | | |
| Minimize floor space used for the mechanical system | | | | | ● | ● |
| Minimize system maintenance | ● | | | | | |
| Avoid having a chimney | | ● | | ● | | ● |
| Maximize the speed of construction | | | | | | ● |

# HEATING AND COOLING SYSTEMS FOR SMALL BUILDINGS: SUMMARY CHART

| | | | | | **PASSIVE SYSTEMS** | | | |
|---|---|---|---|---|---|---|---|---|
| **Electric Baseboard Convectors (page 251)** | **Electric Fan-Forced Unit Heaters (page 252)** | **Radiant Heating (page 253)** | **Wall Furnace and Direct-Vent Space Heaters (page 254)** | **Heating Stoves (page 255)** | **Passive Solar Heating (page 222)** | **Natural Ventilation Cooling (page 225)** | **Thermal Mass Cooling (page 228)** | **Passive Evaporative Cooling (page 231)** |
| Heating only | Heating only | Heating only | Heating only | Heating only | Heating only | Cooing only | Cooling only | Cooling only |
| ● | ● | | ● | ● | | | | |
| | | | | ● | ● | | | |
| | | | ● | ● | ● | ● | ● | ● |
| | | | | | | | | |
| ● | ● | | | | | | | |
| ● | | ● | | | ● | ● | ● | ● |
| | | ● | | | | ● | ● | ● |
| | | | | ● | ● | ● | ● | ● |
| ● | ● | ● | ● | | ● | ● | ● | ● |
| ● | ● | ● | ● | | ● | ● | ● | ● |
| ● | ● | ● | ● | | ● | | | |
| ● | ● | | | | | | | |

# GENERAL CONSIDERATIONS: SMALL BUILDINGS

## CENTRAL SYSTEMS VERSUS LOCAL SYSTEMS

In a *central system*, heat is supplied to a building or extracted from it by equipment situated in a mechanical space—a furnace or a boiler in a basement, for example. Air or water is heated or cooled in this space and distributed to the inhabited areas of the building by ductwork or piping to maintain comfortable temperatures. In a local system, independent, self-contained pieces of heating and cooling equipment are situated throughout the building, one or more in each room. Central systems are generally quieter and more energy-efficient than local systems and offer better control of indoor air quality. Central equipment tends to last longer than local equipment and is easier to service. Local systems occupy less space in a building than central systems because they do not require a central mechanical space, ductwork, or piping. They are often more economical to buy and install. They can be advantageous in buildings that have many small spaces requiring individual temperature control.

Pages 243–248 describe central heating and cooling systems for small buildings, and pages 249–255 describe local systems.

## FUELS

Heating equipment in small buildings may be fueled by oil, pipeline natural gas, liquid propane gas, kerosene, electricity, sunlight, or solid fuels such as coal or wood. Cooling equipment is almost always powered by electricity or, in the case of passive systems, by wind or convective-driven air currents. In functional respects, electricity is the ideal fuel. It is clean, it is distributed through small wires, no chimney is needed, and electrical heating and cooling equipment is compact and often lower in first cost than equivalent fossil-fuel-burning equipment. However, when the efficiencies of remote electrical power generation and distribution are considered, electricity converted directly into heat is less efficient in comparison to systems that rely on the burning of fuels. In most areas, such direct electric heating is also more costly.

Natural gas and oil are usually the fuels of choice for small buildings. Sunlight, wood, and coal are generally less convenient energy sources than electricity, gas, and oil. They are appropriate in particular buildings where owner preferences and building occupancy patterns permit or encourage their use.

On-site storage requirements for the various fuels are summarized in the table below.

### TYPICAL DIMENSIONS OF FUEL STORAGE COMPONENTS

| Component | Width | Depth | Height |
|---|---|---|---|
| Coal storage, minimum, 1 ton (1 tonne) | 4'-0"<br>(1.2 m) | 4'-0"<br>(1.2 m) | 4'-0"<br>(1.2 m) |
| Firewood storage, minimum, ½ cord | 4'-0"<br>(1.2 m) | 4'-0"<br>(1.2 m) | 4'-0"<br>(1.2 m) |
| Liquid propane tanks, upright cylinders | 16" (410 mm) diameter | | 60"<br>(1525 mm) |
| Liquid propane tank, horizontal | 41" (1040 mm) diameter,<br>16'-3" (5.0 m) long | | |

There are many sizes of propane tanks, of which these are two of the most common. Upright cylinders are located outdoors, usually against the wall of the building, often in pairs. They may not be closer than 36" (915 mm) to a door or a basement window. The horizontal tank must be at least 25' (7.6 m) from the building or a property line and may be buried if desired.

| Component | Width | Depth | Height |
|---|---|---|---|
| Oil or kerosene storage tank, 275 gal (1000 l) | 27"<br>(685 mm) | 60"<br>(1525 mm) | 54"<br>(1375 mm) |

For greater capacity, multiple tanks may be installed inside the building, or a larger tank may be buried just outside the foundation.

# FORCED AIR HEATING AND COOLING

## Description

A furnace heats air with a gas flame, an oil flame, or electric resistance coils. The heated air is circulated through the inhabited space by a fan and a system of ductwork. With an *upflow furnace*, the horizontal ducts are located above the furnace at the ceiling of the floor on which the furnace is located. With a *downflow furnace*, the ducts are located beneath the furnace in the crawlspace or floor slab. A third type, the *horizontal furnace*, is designed to fit in a low attic or under-floor crawlspace.

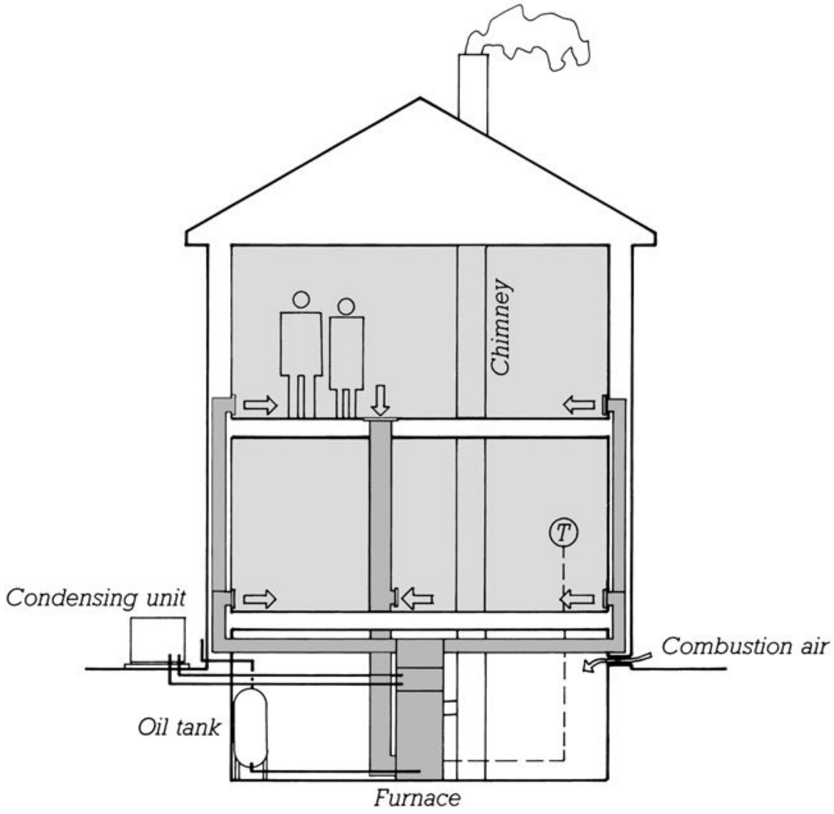
Cooling capability may be added to the furnace by installing evaporator coils in the main supply ductwork adjacent to the furnace. An outdoor compressor and condensing unit supplies cold refrigerant to the evaporator coils through small-diameter insulated tubing.

## Typical Applications

Forced air heating and air conditioning is the most versatile and most widely used system for heating and cooling small buildings. Multiple furnaces may be installed to establish multiple zones of control and to heat and cool buildings of up to 10,000 sq ft (1000 m$^2$) or more.

## Advantages

A forced air system can incorporate every type of humidification, dehumidification, air filtration, and cooling equipment. If properly designed, installed, and maintained, it is quiet and fuel efficient and distributes heat evenly.



**UPFLOW FURNACE**

## Disadvantages

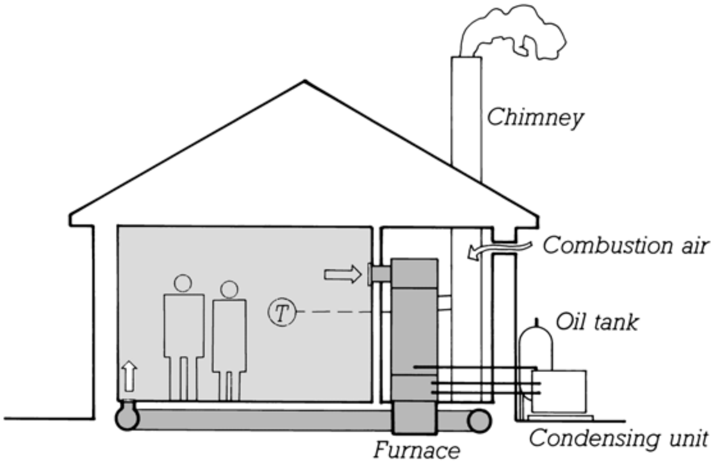
Multiple zones of control are relatively difficult to create and can be wasteful of energy.

## Major Components

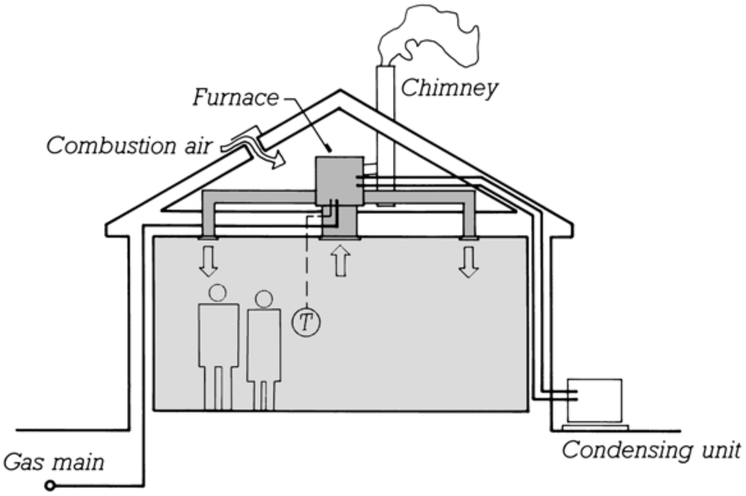
Furnace, fuel storage, chimney, ductwork, and, if cooling capability is included, an outdoor condensing unit. Some high-efficiency gas furnaces may be vented through the wall and do not require a chimney. Typical dimensions for these components are summarized in the table on the facing page. For the dimensions of fuel storage components, see page 242.

## Variations

**1.** A *heat pump furnace* uses a reversible refrigeration cycle to create and circulate either heated or cooled air as required. An outdoor heat pump unit either extracts heat from the outdoor air and releases it through coils in the furnace or extracts heat from the coils in the furnace and releases it to the outdoor air, depending on whether heating or cooling is required.



**DOWNFLOW FURNACE ON SLAB**



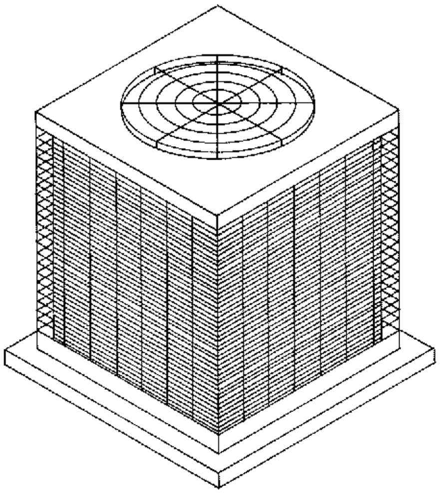
**HORIZONTAL FURNACE IN ATTIC**

# FORCED AIR HEATING AND COOLING

A heat pump furnace is generally economical to operate in moderate climates, but when outdoor temperatures fall well below freezing, the heat pump cycle becomes inefficient and is turned off automatically. Electric resistance coils are then activated to generate heat, which raises operating costs dramatically. For this reason, heat pumps are not usually used in severe climates unless they use water or earth as a heat source rather than air. Heat pump furnaces are available in vertical upflow, vertical downflow, and horizontal configurations and are similar in dimension to other furnaces.

**2.** A *multifuel furnace* is designed to burn solid fuel (wood or coal) as well as a backup fuel (gas or oil). It is larger and more expensive than a single-fuel furnace.

**3.** A *packaged system*, either single-packaged or split-packaged, is often used to heat and cool small commercial, industrial, and institutional buildings. For information on packaged systems, see pages 186–187.



**CONDENSING UNIT**

### TYPICAL DIMENSIONS OF COMPONENTS OF FORCED AIR HEATING SYSTEMS

| Component | Width | Depth | Height |
|---|---|---|---|
| Chimney, masonry | 20"<br>(510 mm) | 20"<br>(510 mm) | [a] |
| Chimney, metal | 10" (255-mm) diameter | | [a] |
| Condensing unit, outdoor | | | |
| Small | 24"<br>(610 mm) | 24"<br>(610 mm) | 24"<br>(610 mm) |
| Large | 40"<br>(1015 mm) | 50"<br>(1270 mm) | 33"<br>(840 mm) |
| Ducts, sheet metal | | | |
| Main horizontal supply and return ducts, each | 24"<br>(610 mm) | | 12"<br>(305 mm) |
| Supply risers, typical (notice that these are made to fit between wall studs) | 10"<br>(255 mm)<br>12"<br>(305 mm)<br>7" oval (175 mm | 3.25"<br>(83 mm)<br>3.25"<br>(83 mm)<br>oval) | |
| Return risers (these are usually fewer in number than the supply risers and require special wall framing provisions) | 8"<br>(200 mm) | 14"<br>(360 mm) | |

For duct insulation, add 1" (25 mm) all around. Insulation is recommended on heating ducts and is mandatory on cooling ducts that run through non-air-conditioned space.

Fuel storage — see page 242

| Component | Width | Depth | Height |
|---|---|---|---|
| Furnaces, including adjacent primary ductwork | | | |
| Horizontal furnace | 24"<br>(610 mm) | 84"<br>(1170 mm) | 28"<br>(710 mm) |
| Upright furnace, upflow or downflow | 24"<br>(610 mm) | 30"<br>(760 mm) | 84"<br>(1170 mm) |
| Multifuel furnace, upright, upflow | 48"<br>(1220 mm) | 60"<br>(1525 mm) | 84"<br>(1170 mm) |

A working space 3’ (900 mm) square is required on the side of the furnace adjacent to the burner. Furnaces have varying requirements for installation clearances to combustible materials; some need only an inch or two.

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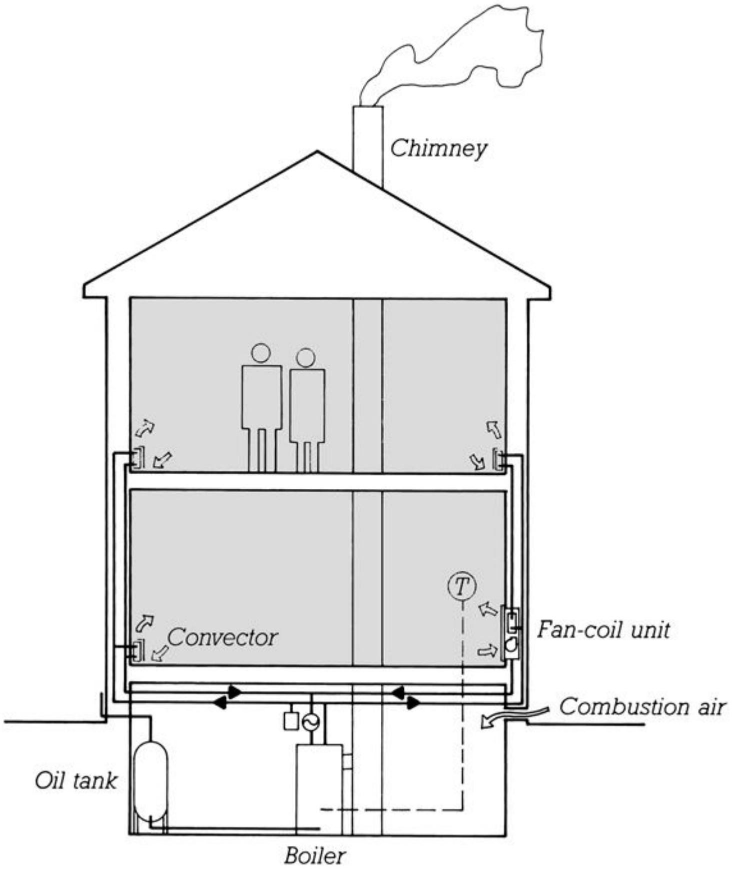
[a] Under most codes, a chimney must extend at least 3' (900 mm) above the highest point where it passes through the roof and at least 2' (600 mm) above any roof surface within a horizontal distance of 10' (3 m).

# HYDRONIC (FORCED HOT WATER) HEATING



## Description

A flame or electric resistance coil heats water in a boiler. Small pumps circulate the hot water through fin-tube convectors, which are horizontal pipes with closely spaced vertical fins mounted in a simple metal enclosure with inlet louvers below and outlet louvers above. The heated fins, working by convection, draw cool room air into the enclosure from below, heat it, and discharge it out the top. Instead of fin-tube convectors, especially where space is tight, fan-coil units, either surface-mounted or wall-recessed, may be used. The fan in a fan-coil unit blows room air past a hot water coil to heat it.

## Typical Applications

Hydronic heating is a premium-quality heating system for any type of building. Radiant systems (described on the facing page) create especially comfortable thermal environments for building occupants.

## Advantages

Hydronic heating is quiet if properly installed and maintained. It gives excellent heat distribution and is easily zoned for room-by-room control by adding thermostatically controlled zone valves or zone pumps at the boiler. The boilers for small-building systems are very compact. Some gas or electric boilers are so small that they can be mounted on a wall.

## Disadvantages

Cooling, air filtration, and humidification, if desired, must be accomplished with independent systems, which raise the overall system cost. The convectors occupy considerable wall perimeter and can interfere with furniture placement.

## Major Components

Boiler, chimney, fuel storage, expansion tank, circulator pumps, zone valves, convector or fan-coil units. Some high-efficiency gas boilers may be vented through a wall and do not require a chimney.

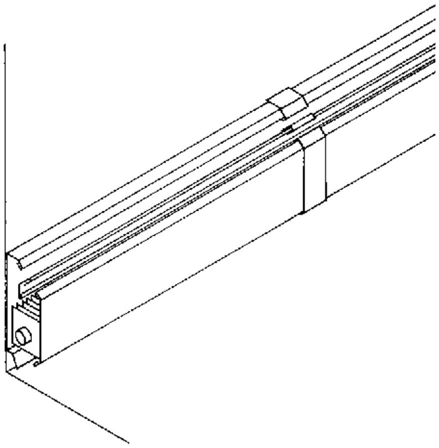
# HYDRONIC (FORCED HOT WATER) HEATING

Typical dimensions for these components are summarized in the table to the right. For dimensions of fuel storage components, see page 242.

## Variations

**1.** A *multifuel boiler* is designed to burn both solid fuel (coal or wood) and a backup fuel (gas or oil). It is larger and more expensive than a single-fuel boiler.

**2.** *Radiant heated floors or ceilings* are warmed with hot water from a hydronic boiler circulated through ceiling panels or floor assemblies. Because these systems rely on relatively large exposed surface areas to radiate heat rather than just to warm the air, they can create a more comfortable thermal environment for the building occupants. (For electric radiant floors and ceilings, see page 253.)

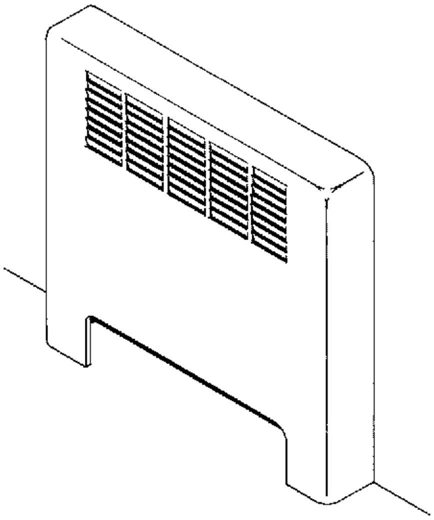


**HYDRONIC CONVECTOR**

**TYPICAL DIMENSIONS OF COMPONENTS OF A HYDRONIC HEATING SYSTEM**

| Component | Width | Depth | Height |
|---|---|---|---|
| Chimney, masonry | 20"<br>(510 mm) | 20"<br>(510 mm) | [a] |
| Chimney, metal | 10" (250-mm) diameter | | [a] |
| Boiler, hydronic, with expansion tank, valves, and pumps (add 10" or 250 mm on two adjacent sides for piping) | | | |
| Upright | 25"<br>(635 mm) | 25"<br>(635 mm) | 84"<br>(2135 mm) |
| Wall-mounted, gas or electric | 30"<br>(760 mm) | 24"<br>(610 mm) | 84"<br>(2135 mm) |
| Solid fuel or combination fuel | 36"<br>(900 mm) | 60"<br>(1530 mm) | 84"<br>(2135 mm) |
| A boiler requires a working space 3' (910 mm) square on the side adjacent to the burner. Required clearances to combustible surfaces vary, depending on the design of the boiler; for some boilers, they may be as little as an inch or two. | | | |
| Convector, baseboard | 3"<br>(75 mm) | 7.5"<br>(190 mm) | |
| Fan-coil units | | | |
| Recessed or surface-mounted | 24"<br>(610 mm) | 4"<br>(100 mm) | 30"<br>(760 mm) |
| Toespace heater | 21"<br>(535 mm) | 18"<br>(460 mm) | 4"<br>(100 mm) |

[a] Under most codes, a chimney must extend at least 3' (900 mm) above the highest point where it passes through the roof and at least 2' (600 mm) above any roof surface within a horizontal distance of 10' (3 m).



**FAN-COIL UNIT**

# ACTIVE SOLAR HEATING

## Description

Outdoor south-facing collector panels, usually mounted on the roof of the building, are heated by sunlight. A pump or fan circulates liquid or air to withdraw the heat from the panels and store it in a tank of liquid or a bin of rocks or phase-change salts. This storage is usually located in the basement or a mechanical equipment room. A fan circulates indoor air through a heat exchanger coil filled with the warm storage liquid, or through the rock bin, and distributes the heated air to the inhabited space of the building through a system of ductwork.

## Typical Applications

Active solar heating is feasible in buildings that are exposed to sunlight throughout the day in climates with a high percentage of sunny weather during the winter.

## Advantages

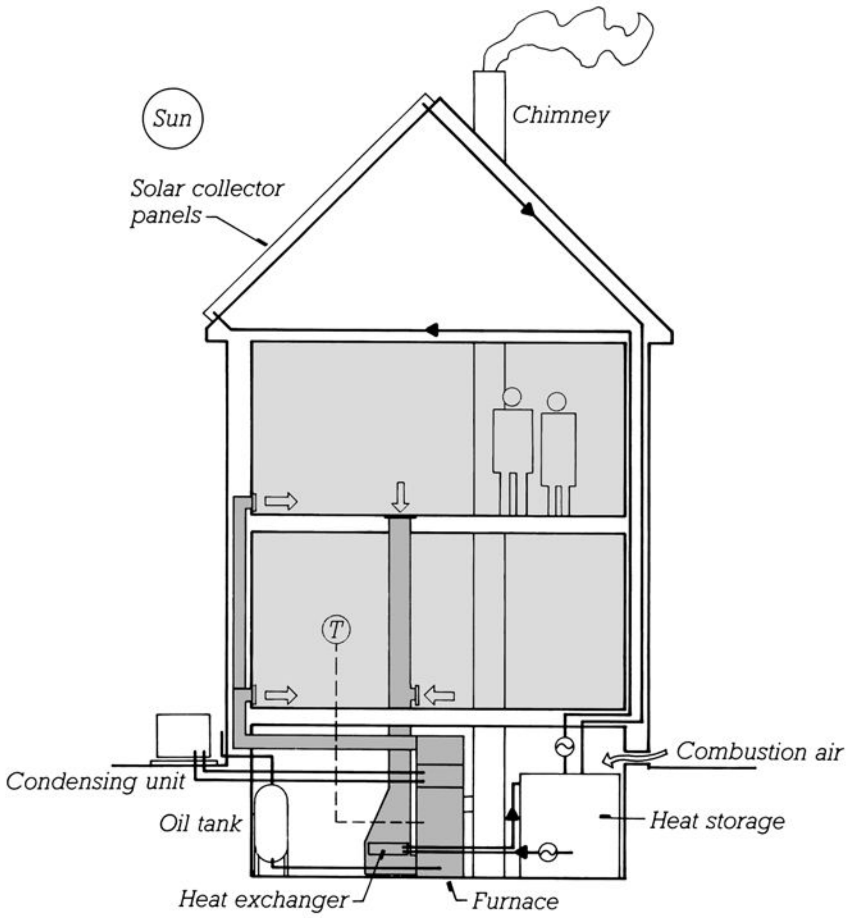
No fuel is required. Only relatively small quantities of electricity are required to power pumps or fans.

## Disadvantages

The initial cost of active solar heating systems tends to be high. The collector surfaces may become a prominent part of the architecture of the building. A backup heating system (such as forced air or hydronic heating) is usually required to heat the building during extended sunless periods. Cooling must be done by a separate system.

## Major Components

Solar collector panels, heat storage tank or bin, ductwork for air collectors or piping for water collectors, heat exchanger, and building heating ductwork. Typical dimensions for these components are summarized in the table to the right. For the dimensions of fuel storage components, see page 242.



## Variations

A heat pump may be added to the system to draw heat from the storage medium at relatively low temperatures and distribute it to the occupied spaces at higher temperatures. This provides a higher degree of comfort and increases the efficiency of the solar collectors.

Solar collector panels may be used to provide heat to the building domestic water system, either in addition to, or in lieu of, providing space heating.

**TYPICAL DIMENSIONS OF ACTIVE SOLAR HEATING COMPONENTS**

| Component | Width | Depth | Height |
|---|---|---|---|
| For dimensions of the backup furnace, chimney, fuel storage, and ductwork, see pages 242 and 245. | | | |
| Collector panels, average residence | 24'<br>(7.3 m) | 6"<br>(150 mm) | 20'<br>(6 m) |
| Collector panels should face within 20° of true south and should be sloped at an angle to the ground equal to or up to 15° more than the latitude of the site. | | | |
| Heat exchanger with ductwork | 30"<br>(760 mm) | 30"<br>(760 mm) | 30"<br>(760 mm) |
| Heat storage | | | |
| Rock bed | minimum of 600 ft$^3$ (17 m$^3$) | | |
| Water storage tank | 8' (2.4 m) diameter | | 7' (2.1 m) |

# PACKAGED EVAPORATIVE COOLER

## Description

A fan blows warm, dry outside air through a wetted pad. Water evaporates from the pad into the air, cooling the air by extracting from it the latent heat of vaporization. The fan circulates the cooled, humidified air through the building. The metal cabinet in which the pad and fan are placed is usually located on the roof or adjacent to the building.

## Typical Applications

Evaporative coolers are used to cool buildings in which humidity control is not critical in hot, dry climates.

## Advantages

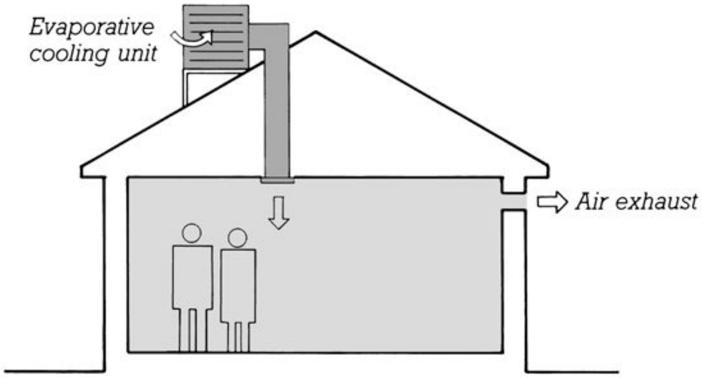
Cooling costs are significantly lower than those of refrigeration-cycle systems. No environmentally hazardous refrigerants are used in the equipment.

## Disadvantages

Evaporative coolers are only suitable for dry climates where added humidity does not decrease occupant comfort. The system is ineffective in humid climates. A separate system is required for heating the building.

## Major Components

Evaporative cooling unit, ductwork. Typical dimensions for these components are summarized in the accompanying table.



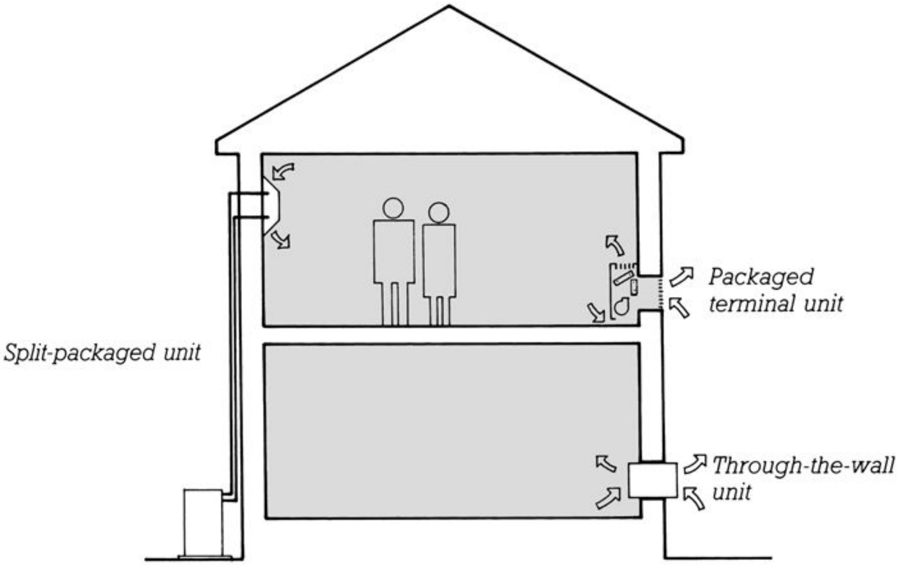
**TYPICAL DIMENSIONS OF EVAPORATIVE COOLING SYSTEM COMPONENTS**

| Component | Width | Depth | Height |
|---|---|---|---|
| Evaporative cooler, average | 36–48"<br>(915–1220 mm) | 36–48"<br>(915–1220 mm) | 24–36"<br>(610–915 mm) |
| Duct | 18"<br>(460 mm) | 18"<br>(460 mm) | |

# PACKAGED TERMINAL UNITS AND THROUGH-THE-WALL UNITS

Packaged terminal units and through-the-wall units are used extensively in small as well as large buildings. See page 178 for more detailed information on these systems.

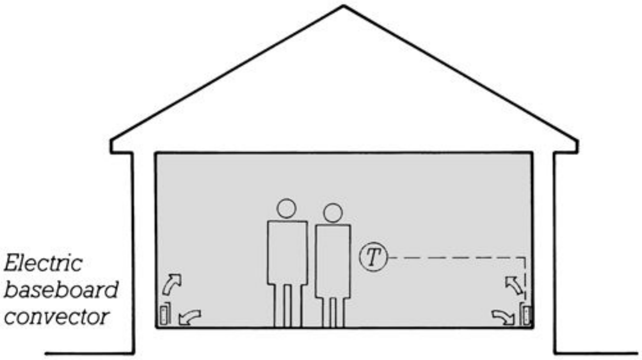
Small split-packaged units are also available for use in small buildings.



# ELECTRIC BASEBOARD CONVECTORS

## Description

Electric resistance wires in sheet metal enclosures are installed around the perimeter of the room at the junction of the floor and the wall. Room air circulates through slots in the enclosures by means of convection and is heated by the resistance wires.



## Typical Applications

Heating systems in buildings of any type, especially where electricity costs are low.

## Advantages

Electric baseboard convectors are quiet and distribute heat evenly. Each room has individual temperature control. Installation costs are low. No chimney is required.

## Disadvantages

The baseboard convectors occupy considerable wall perimeter and can interfere with furniture placement. There is no means of controlling humidity or air quality. Electricity is an inefficient source of heat, and in most areas it is expensive in comparison to other fuels. A separate system is required for cooling.

## Major Components

Electric baseboard convector units. A typical convector is 3 in. (75 mm) deep and 7.5 in. (190 mm) high and extends for some feet along a wall.

# ELECTRIC FAN-FORCED UNIT HEATERS

## Description

Fan-forced electric unit heaters are compact units inside which a fan draws in room air and heats it by passing it over electric resistance wires before blowing it back into the room.

## Typical Applications

Any room or building that requires electric heating from small sources.

## Advantages

Fan-forced unit heaters are economical to buy and install, and they do not interfere with furniture placement as much as baseboard convectors. Each room has individual temperature control. No chimney is required.

## Disadvantages

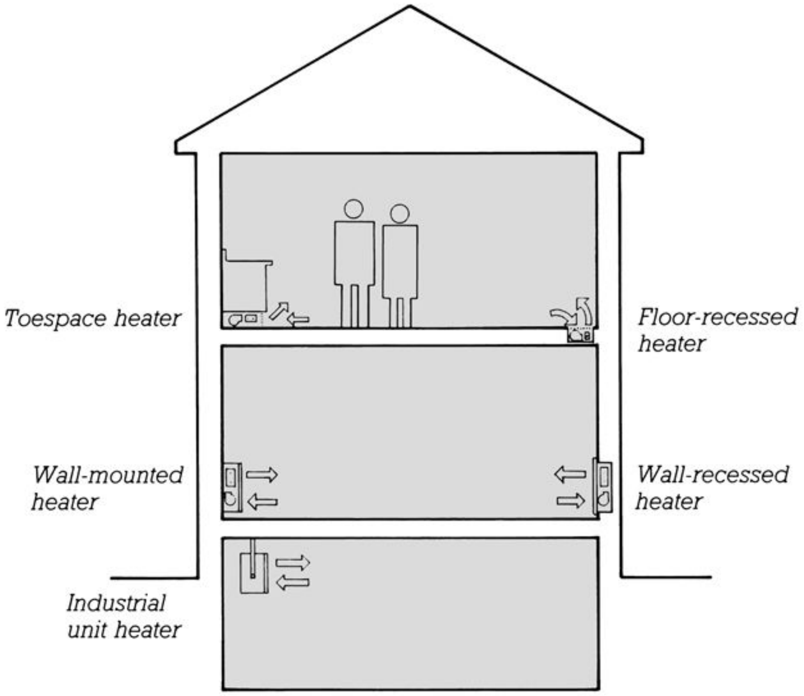
Heat distribution in the room can be uneven, and the fans become noisy unless they are maintained regularly. There is no means of controlling humidity or air quality. Electricity is an inefficient source of heat, and in most areas it is expensive in comparison to other fuels. Separate systems are required for humidification and cooling.

## Major Components

Electric fan-forced unit heaters. Typical dimensions for these components are summarized in the table to the right.

## Variations

Fan-forced unit heaters are available for wall mounting in recessed or surface-mounted configurations. *Toespace heaters* are designed for use in the low, restricted space under kitchen cabinets or shelves. Recessed floor units lie beneath a simple floor register. Industrial unit heaters are mounted in rectangular metal cabinets that are designed to be suspended from the roof or ceiling structure.



**TYPICAL DIMENSIONS OF ELECTRIC FAN-FORCED HEATERS**

| Component | Width | Depth | Height |
|---|---|---|---|
| Floor-recessed heater | 16"<br>(400 mm) | 8"<br>(200 mm) | 8"<br>(200 mm) |
| Industrial unit heater | 16"<br>(400 mm) | 12"<br>(300 mm) | 16"<br>(400 mm) |
| Toespace heater | 24"<br>(610 mm) | 12"<br>(300 mm) | 4"<br>(100 mm) |
| Wall-recessed or wall surface-mounted heater | 16"<br>(400 mm) | 4"<br>(100 mm) | 20"<br>(510 mm) |

# ELECTRIC RADIANT HEATING

### Description

Electric resistance heating wires are embedded in the ceiling or floor. The warm surface radiates heat directly to the body and also warms the air in the room.

### Typical Applications

Residences, nursing homes.

### Advantages

Heating is even and comfortable. No heating equipment is visible in the room.

### Disadvantages

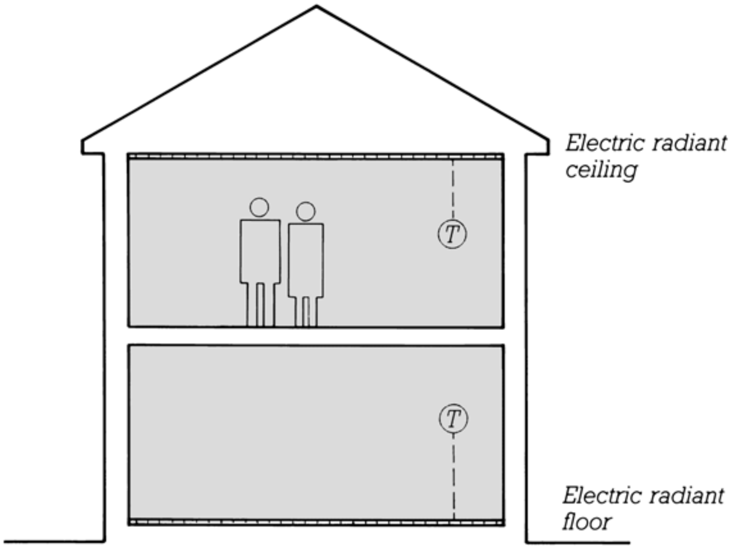
The system is slow to react to changing needs for heat. Tables and desktops beneath a radiant ceiling cast cold “shadows" on the legs and feet. Carpeting and furniture reduce the effectiveness of radiant floor panels. Cooling and humidity control must be provided by a separate system. Electricity is an inefficient source of heat, and in most areas it is expensive in comparison to other fuels.

### Major Components

Resistance wires, resistance mats, or prefabricated, electrified ceiling panels.

### Variations

Ceiling or floor radiant panels may be heated by hot water coils fed from a hydronic boiler.

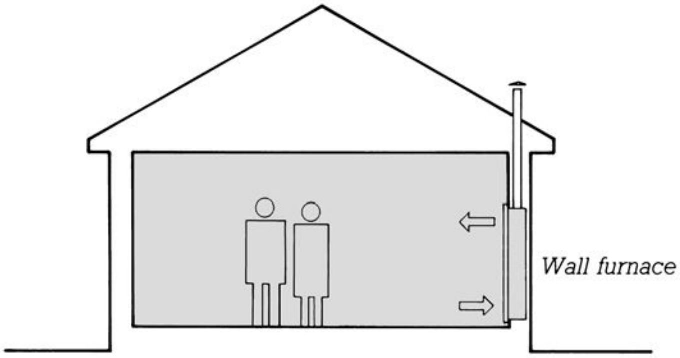


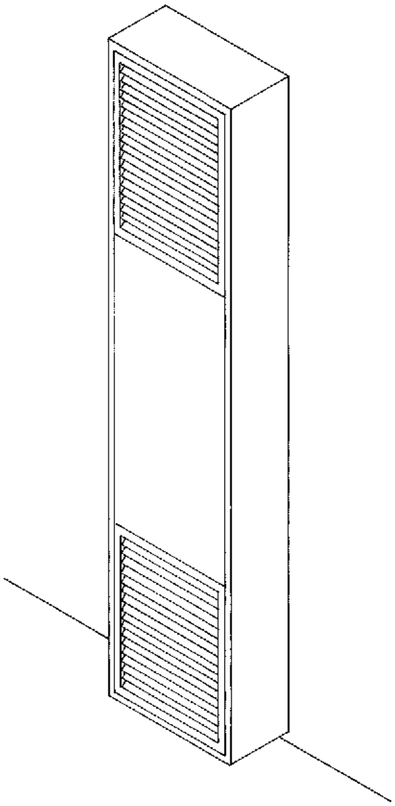
# WALL FURNACE AND DIRECT-VENT SPACE HEATERS

## Description

A wall furnace is a tall wall-recessed or surface-mounted heating unit in which air flows from the room and circulates by convection past metal heat exchange surfaces warmed by a gas flame. Most wall furnaces can heat the spaces on both sides of the wall. Sometimes a short run of ductwork can be added to circulate heat to a third room.

*Direct-vent space heaters* are a newer generation of self-contained heating units. Inside air is fan-forced over a sealed burner unit. The unit draws exterior air for combustion and may be fueled by kerosene, natural gas, or propane. In comparison to wall furnaces, direct-vent space heaters are smaller in size, have greater fuel efficiency, provide improved heat distribution, and offer more choices of fuel source. These units are usually surface-mounted on the inside of an exterior wall, or vent pipes may be extended 10 to 15 ft (3 to 4.5 m) horizontally or vertically to permit more choice in heater location.





WALL FURNACE

## Typical Applications

Low-cost dwellings, offices, and motels in mild climates.

## Advantages

Both systems are inexpensive to buy and install. Direct-vent space heaters are highly fuel efficient.

## Disadvantages

Both systems require vent pipes to the outdoors, they distribute heat unevenly, and they are unattractive visually. Cooling and humidity control must be provided by separate systems.

## Major Components

For wall furnaces, a gas meter and service entrance or a propane tank and regulator, gas piping, wall furnace, and vent pipes through the wall or to the roof. A typical wall furnace is 14 in. wide, 12 in. deep, and 84 in. high (360 × 305 × 2135 mm). The vent pipe to the roof is typically a 4-in. (100-mm) oval that may be concealed between the studs in a wall.

For direct-vent space heaters, the fuel supply may consist of a gas service entrance and meter, propane tank and regulator, or kerosene tank. Kerosene may be gravity-fed, or if the heater is above the level of the tank, a lift pump may be used. Heater unit dimensions are 16–38 in. wide, 9–16 in. deep, and 21–28 in. high (405–965 × 230–450 × 535–710 mm). Dual concentric vent pipes that provide both fresh air intake and combustion exhaust may be extended through the exterior wall or roof and range in size from 2 to 3 in. (50 to 75 mm) in outside diameter.

# HEATING STOVES

## Description

Heating stoves are small appliances that sit conspicuously within each area they heat. They burn wood, coal, gas, oil, or kerosene and transmit heat to the room and its occupants by a combination of convection and radiation.

## Typical Applications

Residential, industrial, and commercial buildings, especially in areas where firewood or coal is inexpensive and readily available. Wood- and coal-burning stoves are frequently used as supplementary sources of heat in centrally heated houses.

## Advantages

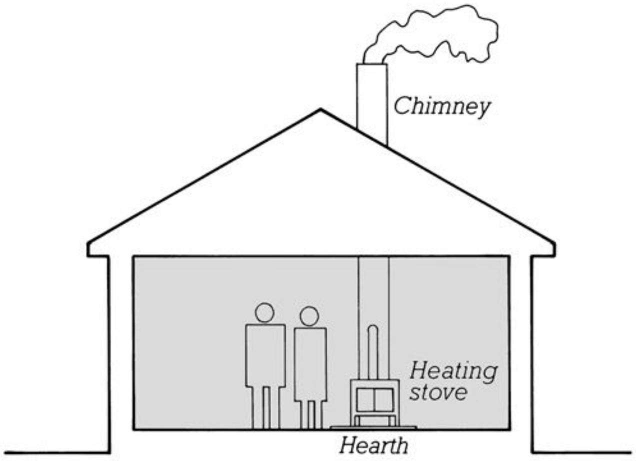
Wood and coal are cheap fuels in many areas, and the experience of tending a stove and basking in its warmth can be aesthetically satisfying. Some stoves are visually attractive.

## Disadvantages

Heating stoves use a surprisingly large amount of floor space and require chimneys. Most stoves are hot enough to burn the skin. They do not distribute heat evenly. Solid-fuel stoves require constant tending and are difficult to control precisely. Solid fuel and ashes generate considerable dirt within the building. A stove becomes a fire hazard unless it and its chimney are conscientiously maintained and operated. Most solid-fuel stoves pollute the air due to incomplete combustion.

## Major Components

Chimney, stove and stovepipe, floor protection, wall protection, fuel storage, ash storage for solid-fuel stoves. Typical dimensions for these components are summarized in the table to the right. For dimensions of fuel storage components, see page 242.



**TYPICAL DIMENSIONS OF HEATING STOVES**

| Component | Width | Depth | Height |
|---|---|---|---|
| Ash storage | Covered metal bucket 14" (360 mm) in diameter | | |
| Chimney, masonry | | | |
| One stove | 20"<br>(510 mm) | 20"<br>(510 mm) | [a] |
| Two stoves | 20"<br>(510 mm) | 28"<br>(710 mm) | [a] |
| Chimney, metal | 10" (254-mm) diameter | | |
| Fuel storage: see page 242 | | | |
| Stove | | | |
| Gas-fired | 38"<br>(965 mm) | 13"<br>(330 mm) | 40"<br>(1015 mm) |
| Oil-fired | 32"<br>(815 mm) | 30"<br>(760 mm) | 40"<br>(1015 mm) |
| Wood-fired | Varies widely up to the dimensions shown for gas-fired and oil-fired stoves | | |
| Stovepipe, uninsulated, typical | 7" (180 mm) diameter | | |
| Stovepipe, insulated, typical | 9" (230 mm) diameter | | |

Heating stoves typically require a clearance of 36" (914 mm) to combustible or plaster surfaces. They also require a noncombustible hearth that extends 12" (305 mm) to each side and to the back of the stove and 18" (460 mm) to the front. Some stoves are shielded to allow them to be as close as 12" to combustible surfaces to the back and sides. An uninsulated metal stovepipe may not come closer than 18" (460 mm) to the ceiling. Insulated pipes are usually designed for a 2" (51-mm) clearance to combustible materials.

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[a] Under most codes, a chimney must extend at least 3' (900 mm) above the highest point where it passes through the roof and at least 2' (600 mm) above any roof surface within a horizontal distance of 10' (3 m).

## WATER SUPPLY

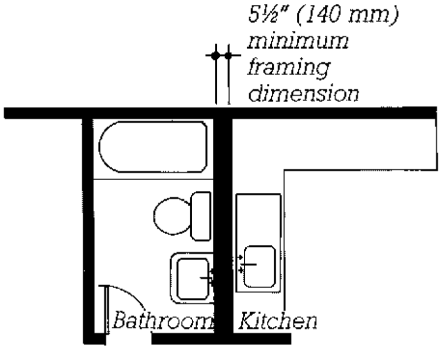
Water from a municipal main reaches the building via an underground service pipe and a water meter. In warm climates, the meter may be outside the building, but in cold climates, it must be installed in a heated space, usually the basement or the mechanical equipment room. In many areas an electronic readout, connected by wires to the inside water meter, is mounted on the outside of the building so that the meter reader does not need to enter the building.

From the water meter, domestic cold water flows directly to the fixtures by means of small-diameter copper or plastic pipes. If the water is "hard" (contains a heavy concentration of calcium ions), a water softener may be installed to remove these ions from the water that goes to the domestic water heater. The water heater uses a gas flame, an oil flame, solar-heated liquid, or electric resistance heating to warm the water to a preset temperature at which it is held in an insulated tank for subsequent use. A tree of hot water piping parallels the cold water piping as it branches to the various fixtures in the building. Supply piping should be kept out of exterior walls of buildings in cold climates to prevent damage to piping from wintertime freezeups.

If water is obtained from a private well, it is lifted from the well and pressurized by a pump. If the well is deep, the pump is usually placed at the well bottom. If the well is less than approximately 20 to 25 ft (6 to 8 m) deep, the pump may be located inside the building. In either case, the pump pushes the water into a pressure tank, from which it flows on demand into the hot and cold water piping. The pressure tank may be located inside the well, or in the basement or mechanical equipment room of the building.

## WASTE PIPING AND SEWAGE DISPOSAL

Sewage flows from each fixture through a trap into waste pipes that drain by gravity. To ensure that the traps do not siphon dry and to maintain constant atmospheric pressure in the waste piping, a vent pipe is attached to the waste system near each trap. The vent pipes rise through the building until they penetrate the roof, where they are left open to the air. The vent pipes may be gathered together into a single pipe in the attic of the building to minimize the number of roof penetrations. A horizontal run of vent can be used to move a plumbing vent to a less prominent rooftop location.



The waste piping descends through the building, gathering waste from all the fixtures, until it reaches the ground, the crawlspace, or the basement. If it lies above the sewer or the private disposal system at this point, it turns to an almost horizontal orientation, sloping toward its outlet (the sewer main or the septic tank) at a pitch of at least 1:100. If it lies below the elevation of its outlet at this

### TYPICAL DIMENSIONS OF PLUMBING COMPONENTS

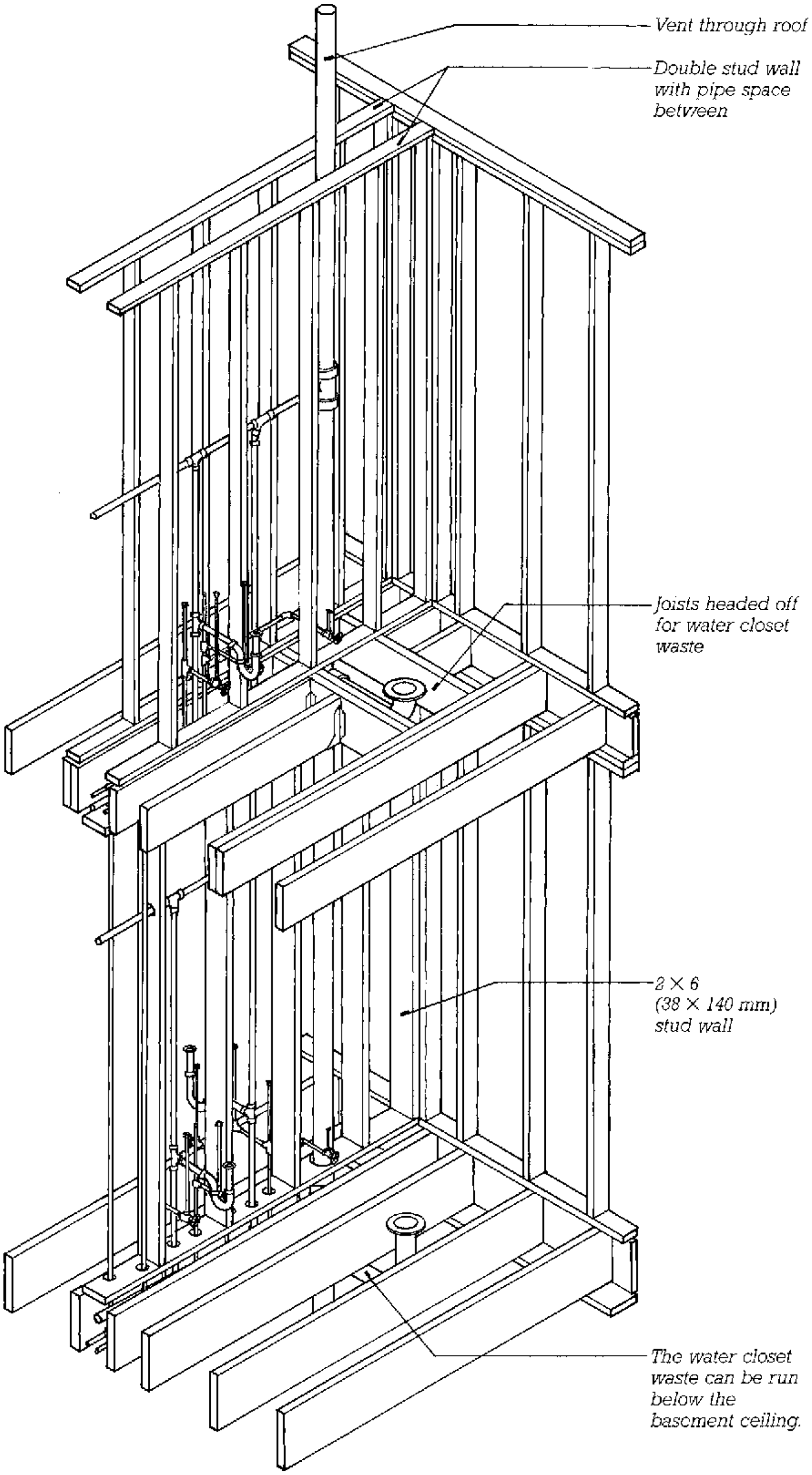
| Component | Width | Depth | Height |
|---|---|---|---|
| Gas meter and piping | 18" (460 mm) | 12" (305 mm) | 24" (610 mm) |
| Sewage disposal, private | | | |
| The size and configuration of private sewage disposal systems vary widely, depending on soil conditions, topography, local laws, and the required capacity of the system. As a starting point, allow an area of level or nearly level ground 40' × 80' (12 × 25 m), with its short side against the building. No part of this area may be closer than 100' (30 m) to a well, pond, lake, stream, or river. | | | |
| Water heater | | | |
| Gas-fired | 20" (510-mm) diameter | | 60" (1525 mm) |
| Electric | 24" (610-mm) diameter | | 53" (1350 mm) |
| Water meter and piping | 20" (510 mm) | 24" (305 mm) | 10" (255 mm) |
| Water pressure tank for a pump that is located in a well | 20" (510-mm) diameter | | 64" (1625 mm) |
| Water pump and pressure tank for a shallow well | 36" (915 mm) | 20" (510 mm) | 64" (1625 mm) |
| Water softener | 18" (460-mm) diameter | | 42" (1070 mm) |

point, an automatically operated underground ejector pump must be installed to lift the sewage and empty it into the outlet.

Waste and vent piping is larger in diameter than supply piping and requires careful planning to fit efficiently into a building. Bathrooms and toilet rooms should be stacked to avoid horizontal displacements of the waste and vent stacks. For maximum economy, fixtures should be aligned along thickened plumbing walls, and rooms containing fixtures should be clustered back-to-back around the plumbing walls. The major horizontal runs of waste piping should be located in a crawlspace, beneath a slab, or just inside the perimeter of a basement. Some typical wood framing details for plumbing walls are shown in the diagram to the right.

Private sewage disposal systems vary considerably in configuration and size, depending chiefly on soil conditions and local health regulations. The most common type includes a septic tank, usually 1000 to 1500 gal (4000 to 6000 l) in capacity, in which the sewage is digested by anaerobic action. Effluent from the septic tank flows by gravity to a disposal field of open-jointed or perforated pipe laid below ground in a bed of crushed stone. In nearly all areas of North America, private sewage disposal systems may be designed only by a qualified engineer. The engineer's design is based on soil tests that in some municipalities may be performed only during those limited periods of the year when the soil is in its most saturated condition, and a building permit will not be issued until a permit has been granted for the construction of the disposal system. This can potentially delay the start of a construction project for many months.

Typical dimensions of plumbing components are summarized in the table on the facing page.



FRAMING DETAILS FOR PLUMBING WALLS

## GAS SERVICE

Natural gas is distributed to buildings through mains located beneath the street. Each building is served by an underground pipe that surfaces at a gas meter and pressure regulator next to or just inside the building. From this service entrance, the gas is piped through the building to the various appliances— furnaces, boilers, water heaters, clothes dryers, fireplaces, barbecues, kitchen ranges, and industrial equipment.

Where there are no gas mains, liquid propane gas can be delivered by tanker truck to pressurized tanks outside the building. The gas flows from the tanks through a pressure regulator and evaporator into the building's gas piping system.

Gas piping is small in diameter and is made up of threaded iron pipe and fittings. It does not usually require special consideration in the design of the building, but space does need to be provided, usually at the basement ceiling or in the crawlspace or slab, for long horizontal runs of gas piping.

For dimensions of gas meters in a small building, see the table on page 256. For dimensions of liquid propane storage tanks, see the table on page 242.

## SPRINKLER SYSTEMS IN SMALL BUILDINGS

Small building sprinkler system requirements vary with the type of Occupancy and size of the building. To determine if sprinklers are required for your project, consult the height and area tables on pages 386–441 for buildings that are regulated by the International Building Code and pages 442–471 for buildings that are regulated by the National Building Code of Canada.

Where the height and area tables indicate that sprinklers are required and no further information is provided about sprinkler system type, a commercial grade (NFPA 13) sprinkler system should be assumed and the guidelines for large building sprinkler systems provided on pages 200 and 208 should be followed.

Where the height and area tables indicate that a lighter duty, NFPA 13R (residential) sprinkler system is permitted, follow the commercial grade sprinkler system guidelines noted above, with the following exceptions:

- Due to reduced water supply demands, no fire pump normally is required. Where water supply is inadequate, a gravity tank or air-pressurized tank may provide the necessary backup.
- A relatively small assembly of valves and alarm fittings joins the sprinkler system to the domestic water supply.
- An exterior Siamese fitting for hookup to fire department pumper trucks may be required.
- Dedicated sprinkler riser shafts may not be required. The smaller-diameter piping that is typical of this system may fit comfortably into available wall cavities.
- A maximum coverage of 144 sq ft (13 m$^2$) of floor area per sprinkler head should be assumed.
- Sprinkler coverage does not need to extend into attics, bathrooms, and small bathrooms or closets.

Where the height and area tables indicate that an NFPA 13D (one- and two-family dwelling) sprinkler system is permitted, use the following guidelines:

- This system is connected directly to the building's domestic water supply system. No fire pump is required.
- Assume a maximum coverage of 144 sq ft (13 m$^2$) of floor area per sprinkler head.
- Sprinkler coverage must extend throughout living areas but need not include attics, crawlspaces, small closets, small pantries, small bathrooms, garages, carports, exterior porches, and unheated entry areas.
- Sprinkler piping for this system is small in diameter, takes up little space, and is easy to install. It may be metallic or of several kinds of plastic. Nonmetallic piping must be separated from interior spaces by a layer of gypsum wallboard or other material that offers at least short-term protection from the heat of a fire.

# ELECTRICAL AND COMMUNICATION WIRING FOR SMALL BUILDINGS

Electrical, telephone, data networking, and cable television services reach the building via either overhead or underground wires, depending on the practices of the local utilities. Overhead wires at the street may be converted to an underground service to the building by running the service wires down the face of the pole to the required depth and then laterally to the building. Data networking may also be provided by optic fiber.

An electric power meter is mounted in an accessible location on the outside of the building. Wires from an overhead service arrive at the building above the meter and descend to it in a large cable or a metal conduit mounted on the exterior wall surface. Wires from an underground service are brought up to the meter in a conduit. A cable or conduit from the meter enters the building at the basement or main floor level and connects to the main electric panel, which should be as close to the meter as possible.

From the main panel, wiring fans out to branch panels and individual circuits. Exposed wiring or wiring in masonry or concrete must be placed in metal or plastic conduits. In frame buildings, most wiring is done with flexible plastic-sheathed cable that is routed through the cavities of the frame. In a very small building, all the branch circuits connect directly to the main panel. In a larger building, especially one with multiple tenant spaces, most circuits connect to branch panels scattered at convenient points around the building. The branch panels, in turn, are connected by cables or conduits to the main panel.

Panel locations need to be worked out fairly early in the building design process. In small framed buildings, the designer seldom needs to be concerned about providing space for the wires and cables unless the construction system features exposed framing members and decking. In this case, conduit routes for the wiring must be carefully planned to avoid visual chaos.

Wiring systems for telephone service, cable television, data networks, centralized entertainment systems, security systems, smoke and fire alarms, intercoms, antennas, and so on generally have minimal impact on the planning of a small building in the early stages of design. At their simplest, such systems may not require any dedicated space, or may require only small, wall-mounted panels that can share space in general-purpose closets, basements, or mechanical equipment rooms. As systems increase in complexity, dedicated wiring closets may be necessary. Such closets should be centrally located to best accommodate the star topology of most such systems and to minimize the length of individual cable runs. For example, a central stair may offer closet space at its lowest level as well as easy cable access up through the center of the building; at each floor or ceiling level, cables can then branch out to reach their final destinations. Closets must be located so that cable lengths do not exceed their maximum limits for reliable performance. For example, with the most common type of local area network (Category 5) cabling, individual cables should not exceed approximately 285 ft (85 m) in length. To avoid electrical interference from other systems, communications closets should be separated from electrical service entrance cables, service panels, lightning protection, and mechanical equipment by at least 6 ft (1.8 m).

Typical dimensions of components of electrical systems in small buildings are summarized in the table below.

**TYPICAL DIMENSIONS OF COMPONENTS OF ELECTRICAL SYSTEMS**

| Component | Width | Depth | Height |
|---|---|---|---|
| Electric meter | 12"<br>(305 mm) | 9"<br>(230 mm) | 15"<br>(380 mm) |
| Main panel | 14"<br>(360 mm) | 4"<br>(100 mm) | 27"<br>(685 mm) |
| Branch panel | 14"<br>(360 mm) | 4"<br>(100 mm) | 20"<br>(685 mm) |

SECTION

# 5

# DESIGNING FOR EGRESS AND ACCESSIBILITY

# 1

# CONFIGURING THE EGRESS SYSTEM AND PROVIDING ACCESSIBLE ROUTES

***This chapter will assist you in laying out doors, corridors, stairways, exit discharges, and accessible routes for a preliminary building design in accordance with the requirements of the model building codes.***

# COMPONENTS OF THE EGRESS SYSTEM

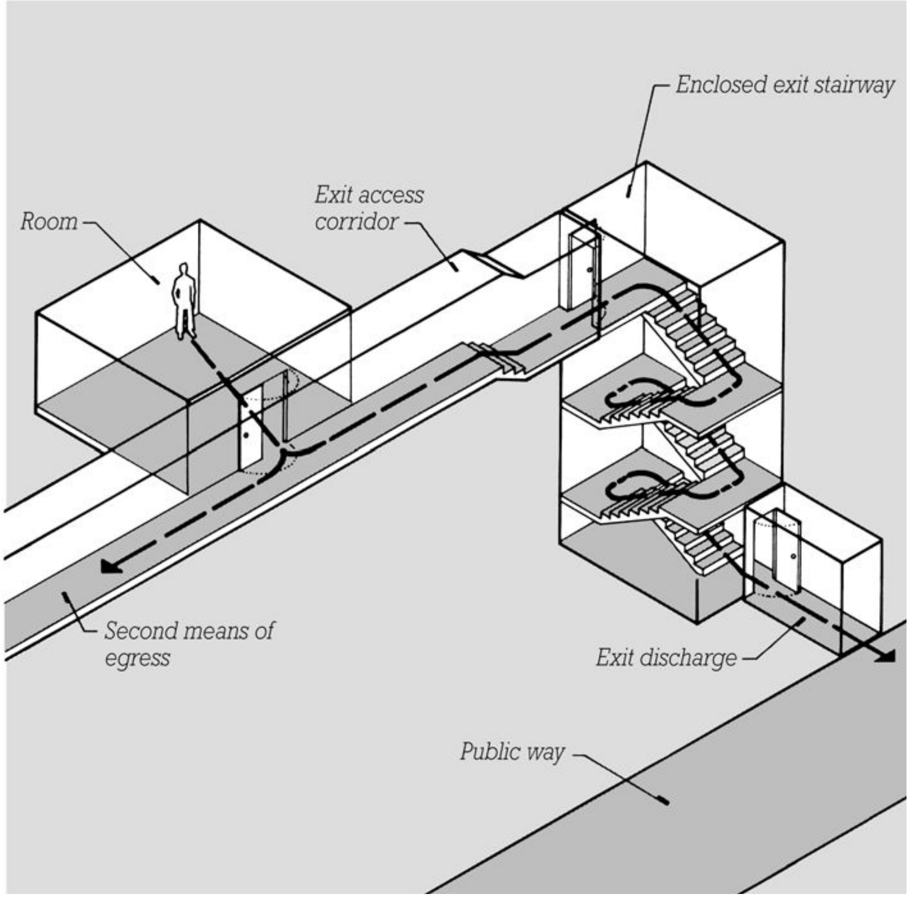
The function of a building egress system is to conduct building occupants to a safe place in case of a fire or another emergency. In most instances, that safe place is a public way or other large, open space at ground level. For the occupants of the upper floors of a tall building, or for people who are incapacitated or physically restrained, the safe place may be a fire-protected area of refuge within the building itself.

A building egress system has three major parts:

**1.** The *exit access* begins at any point in the building accessible to its occupants and continues up to the portion of the egress system termed the *exit*. The exit access may include pathways within a room, aisles between fixed seating, hallways, corridors, ramps, unenclosed stairways, and other spaces.

**2.** The *exit* is the protected portion of the egress system that connects the exit access to the exterior of the building. Most commonly, it is an enclosed, fire-protected stairway that conducts occupants from multiple floors of a building to a door opening to the outside. It may also include similarly enclosed, protected passageways. Or from a ground floor room, the exit may consist of nothing more than a door opening from that room directly to the outside.

**3.** The *exit discharge* is the final portion of the egress system that connects the exit to the public way or another place of safety. In many cases, the exit discharge may consist only of exterior elements, such as sidewalks, stairs, ramps, or courts that lead from the building exit to the public sidewalk or street. In other cases, the exit discharge may include limited portions of the building interior, such as when the egress path leaves an exit stair and passes through a vestibule or ground floor lobby before reaching the building exterior.



These three parts of an egress system are discussed in greater detail on the pages that follow. Also included are simplified standards for the preliminary design of these components, condensed from the model building codes treated in this book.

## EXIT ACCESS PATHS

Every occupied space in a building must have access to a means of egress so that occupants can leave the building safely in an emergency. Where a room or space is small and serves only a limited number of occupants, only a single means of egress may be required. Larger spaces require two or more means of egress that are independent of each other. Multiple egress paths help to ensure that larger numbers of occupants can safely and efficiently exit from a space and provide alternative routes of escape if one pathway is rendered unsafe or unreachable.

Wherever more than one exit access pathway is provided, the capacity of the individual pathways should be balanced so that the loss of any single pathway will not reduce the remaining egress capacity to less than one-half of the total required.

### International Building Code

The International Building Code limits spaces with single means of egress based on the occupancy classification and number of persons within the space. See the table on pages 300–301 for more information. Areas exceeding these limits require at least two independent means of egress. Areas with an occupant load exceeding 500 require three independent means of egress, and those with an occupant load exceeding 1000 require four.

Residential and some institutional occupancies also have special emergency escape and rescue requirements. See page 291 for more information.

### National Building Code of Canada

In the National Building Code of Canada, any room, area, or occupied roof with an occupant load exceeding 60 generally requires two independent ways out. Requirements for independent means of egress also vary with the size of the space, the Occupancy type, and the presence or absence of sprinklers. See the table on pages 306–307 for more information.

Individual dwelling units within Residential Occupancies are permitted to have just one means of egress when a single exit door leads directly to the exterior not more than 1.5 m (5 ft) above grade, and the exit door is within one story of every floor level within the unit or the uppermost floor of the unit opens to an exterior balcony that is not more than 6 m (20 ft) above grade.

See also pages 292–293 for emergency bedroom egress and firefighter access to buildings.

## EGRESS THROUGH ADJACENT SPACES

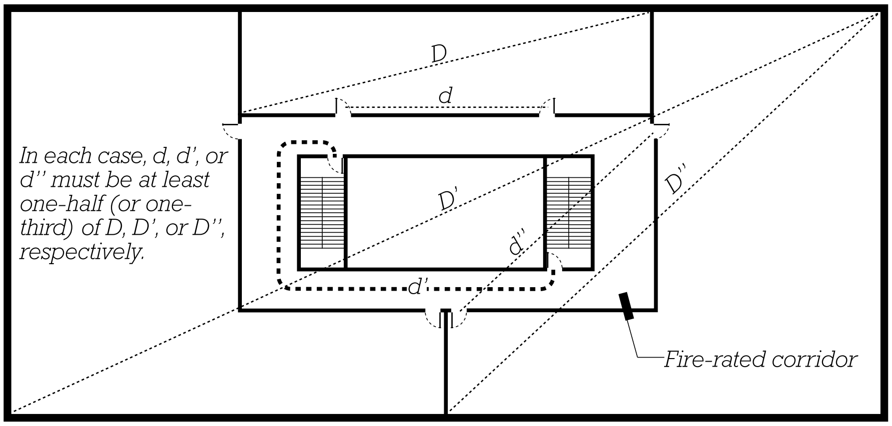
In their most conventional configuration, exit access pathways are expected to proceed from rooms to shared corridors and then to enclosed exits. The International Building Code in some circumstances also permits exit access pathways to flow through intermediate spaces to which the originating space is functionally related. However, once an exit access path reaches a corridor or hallway, it must proceed directly to an exit stair or other exit component and cannot reenter other spaces.

## DISTANCE BETWEEN EXITS

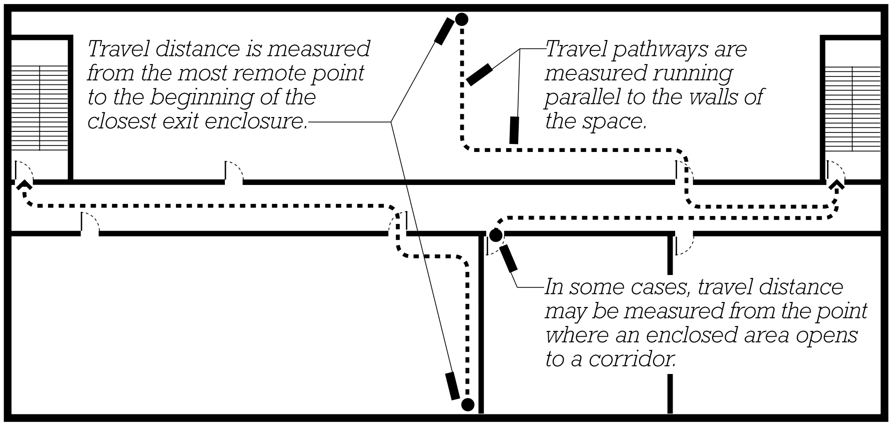
Wherever more than one egress pathway is required from a room or area, these pathways must be sufficiently remote from one another to minimize the possibility that they become simultaneously unsafe or inaccessible in a building emergency.

### International Building Code

In the International Building Code, where a room, space, or whole floor requires more than one way out, at least two of the ways must be separated by a distance of not less than one-half the diagonal measure of the area served. Or, where the building is fully sprinklered, the distance may be reduced to one-third the diagonal measure of the area. Normally, these distances are taken as straight-line measurements. However, when exits off a floor are interconnected by a 1-hour rated corridor, the distance between the two exits is measured along the path of travel in the corridor rather than in a straight line. (See the diagram on this page.) For special exit separation requirements for tall buildings, see page 291.



DISTANCE BETWEEN EXITS



TRAVEL DISTANCE

### National Building Code of Canada

In the National Building Code of Canada, where two egress doorways are required from one space, the doorways must be separated by a distance of at least one-third the diagonal measure of the space served.

When considering exits off a floor, the required distance between exits is one-half the diagonal measure of the floor or 9 m (30 ft)—the lesser of the two measurements when the exits are accessed from a corridor or the greater of the two when no corridor is provided. No minimum distance between exits is required where a floor is subdivided by fire separations into two or more major areas, each containing its own exit.

In this code, distance between doorways or exits is measured as a straight line when open areas are served. Where spaces are subdivided, the distance is measured as the shortest pathway that smoke can take to travel between the doorways or exits, such as along corridors or through other confined spaces.

## MAXIMUM TRAVEL DISTANCE TO THE EXIT

*Travel distance* is measured from the most remote occupied point in a building to the nearest enclosed exit stairway, enclosed exit passageway, or direct exit from the building. Both model building codes limit travel distance so that in the event of an emergency, the amount of time that persons may be exposed to smoke from fire or other hazardous conditions is limited. For common building occupancies, travel distance limits range from 200 to 400 ft (61 to 122 m) in the International Building Code and from 30 to 60 m (98 to 197 ft) in the National Building Code of Canada. See pages 300–301 and 306–307 for more information.

Travel distance must be measured along the actual path an occupant will take to reach the exit portion of the egress system. For example, where a room or space can be expected to be furnished with tables, desks, or arrayed seating, or where other obstacles may prevent a direct line of travel from some parts of the room to its way out, travel distance should be measured along paths that realistically reflect the expected conditions. Usually, such paths are assumed to run parallel to the walls of the space.

Travel within enclosed exit components is not included in travel distance calculations. For example, in a multistory building, travel distance is measured from remote points on any floor to the door leading to an enclosed exit stairway. Travel down the enclosed stairway is not included.

In the International Building Code, travel along open (unenclosed) stairways is included in travel distance measurements. Furthermore, the length of travel along the stair is measured parallel to the plane of the stair, not in horizontal plan projection.

In the National Building Code of Canada, travel distance from rooms or suites separated from the remainder of the floor and opening onto a corridor or exterior passageway may be measured from the doorway of the space leading to the corridor or passageway rather than from the most remote point within the room or suite. On an unsprinklered floor, the separation between the rooms or suites and the remainder of the floor must have at least a 45-minute fire-resistance rating. On sprinklered floors, no fire-resistance rating is required.

For rooms or suites in fully sprinklered buildings, served by a corridor at least 9 m (30 ft) wide and with a ceiling at least 4 m (13 ft) high, this code permits travel distance of up to 105 m (344 ft), provided that, where any space requires more than one means of egress, not more than half the required means of egress utilize the corridor. This exception is primarily intended for commercial mall buildings.

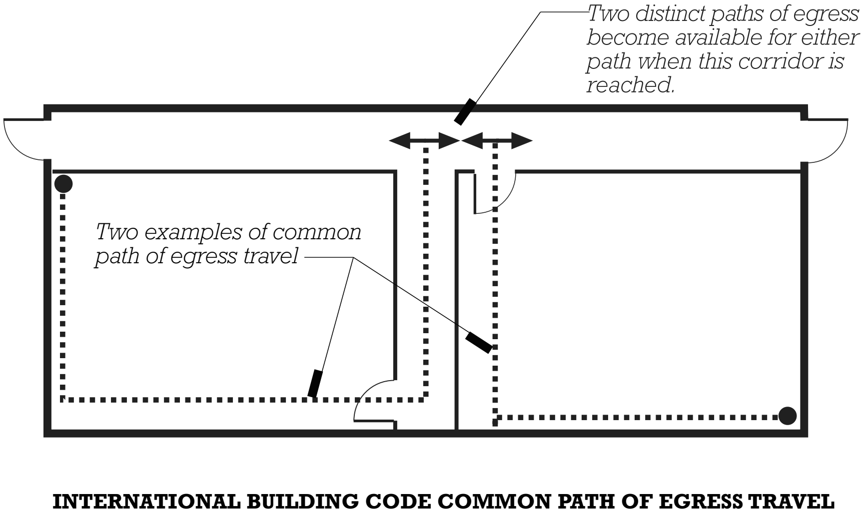
This code also permits large floor areas to forgo other stated travel distance limits when all main aisles in the space lead directly to exits arrayed around the perimeter no greater than 60 m (197 ft) apart. This exception does not apply to F-1 High-Hazard Industrial Occupancies and is mainly intended for large, ground-level assembly spaces where exits lead directly to the exterior.

## TRAVEL LIMITATIONS WITHIN THE EXIT ACCESS

The International Building Code restricts the maximum length of a portion of the exit access called the *common path of egress travel*. This is the length of travel starting anywhere in the building and continuing to a point at which two independent means of egress become available to the occupant. For example, in a room with just one doorway leading to a corridor, where the corridor provides egress in two separate directions, the length of the common path of egress travel would be the travel distance within the room and through the doorway to the corridor. See the diagram on this page.

In the International Building Code, common path of egress travel limits range from 25 to 125 ft (7.6 to 38 m), depending on the Occupancy and the absence or presence of sprinklers. See page 300 for more details. Note that these limits do not apply where floors are permitted to have only one exit (page 272).

In the National Building Code of Canada, where a room or space is permitted only one means of egress, the travel distance from any point in the space to its egress doorway cannot exceed 10 to 25 m (33 to 82 ft), depending on the Occupancy and the presence or absence of sprinklers. See the table on pages 306–307 for more details. Upon leaving the room and entering a corridor or exterior passageway, the occupant must be provided with two independent paths of egress (except where whole-floor, single-exit conditions are permitted).



INTERNATIONAL BUILDING CODE COMMON PATH OF EGRESS TRAVEL

## CORRIDORS

Corridors are dedicated, enclosed exit access components that connect a floor's occupied spaces to its exits. In the event of a building emergency, corridors must provide safe, efficient passage: Corridors must be sufficiently wide to allow free passage of occupants; they must lead to exits that are not so distant as to risk excessive exposure to hazardous conditions; they must be clearly marked and easy to navigate, without lengthy dead ends that could trap occupants who are unfamiliar with the building or who are disoriented by low-visibility conditions; and depending on the type of Occupancy, number of occupants, and presence of sprinklers, corridor enclosures may be required to be fire-resistance rated so as to provide a greater degree of protection to occupants as they move toward exits.

Generally, corridors must lead directly to enclosed exits without passing through intervening rooms. In the International Building Code, foyers, lobbies, and reception areas may be included in the corridor exit access if such rooms are constructed to the same requirements as the corridor. With either code, any use within the exit access system must not intrude into the required egress width of the exit access.

Corridor sizing information can be found on page 301 for the International Building Code and on page 307 for the National Building Code of Canada.

### International Building Code

In the International Building Code, the level of fire resistance required for the walls and floor/ceilings enclosing a corridor varies with the Occupancy classification and the number of occupants served by the corridor, as listed in the table below. (Where an occupant load is indicated, corridors with smaller occupant loads may have unrated enclosures.)

### National Building Code of Canada

In the National Building Code of Canada, corridors must normally be enclosed with 45-minute fire-resistance rated walls and floor/ceiling assemblies. Corridors in some unsprinklered Assembly occupancies must be enclosed with 1-hour rated assemblies. Corridors may be enclosed with unrated assemblies when the floor is fully sprinklered and any of the following conditions apply:

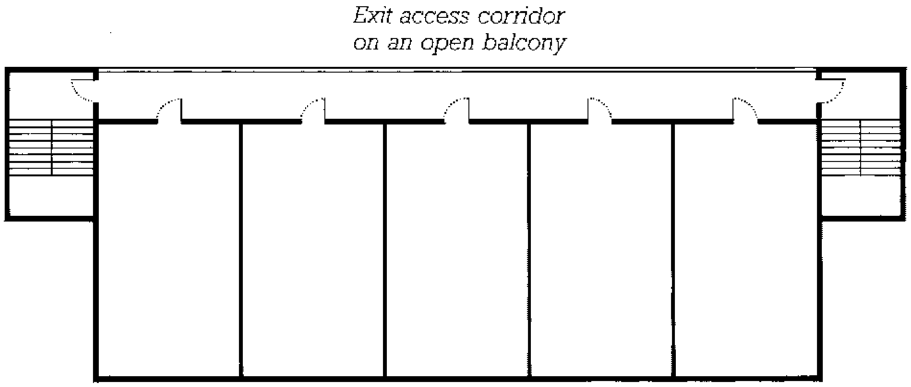
- The floor does not include any B Care, Treatment, Detention, or C Residential Occupancies.
- Travel distance from any point on the floor does not exceed 45 m (148 ft).
- Requirements for mall corridors are met; see the code for details.

| Occupancy | Corridor Protection |
|---|---|
| A, B, E, F, M, S, U, with an occupant load greater than 30 | Unrated if the building is sprinklered throughout; otherwise, 1-hour rated |
| B, corridors within areas requiring only a single exit | Unrated |
| E, where each instruction room and assembly room has at least one door leading directly to the exterior at grade | Unrated |
| All H-1, H-2, H-3 | 1-hour rated |
| H-4, H-5, with an occupant load greater than 30 | 1-hour rated |
| All I-1, I-3 | 1-hour rated |
| All I-2, I-4 | Unrated |
| R, with an occupant load greater than 10 | ½-hour rated |
| R, corridors within dwelling or sleeping units | Unrated |

## EXTERIOR EXIT ACCESS

Exit access ways may include open pathways on the exterior of a building. In cold climates, such areas should be sheltered to prevent the accumulation of ice and snow.

In the International Building Code, exterior access ways qualify as *egress balconies* when one of the long sides of the balcony is at least 50% open to the exterior. Egress balconies leading to only one exit stair must be separated from interior spaces by rated walls and protected door and window openings with fire ratings equal to those required for corridors. Where such balconies have two ways off, adjacent walls, windows, and doors are not required to be fire rated, provided that from any point on the balcony, a fire burning through any one door or window cannot simultaneously block an occupant's access to both ways off the balcony. When designing with egress balconies, this code permits allowable travel distances (page 267) to be increased by the length of the balcony, up to 100 ft (30 m) maximum.

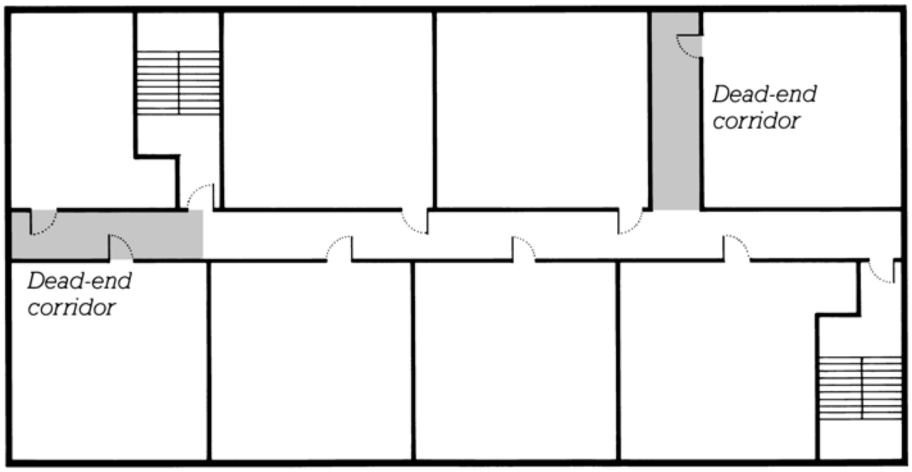


**EXTERIOR CORRIDOR OR EXIT PASSAGEWAY**

The National Building Code of Canada treats exterior passageways as exits rather than exit access. They must be separated from the interior of the building in the same manner as conventional interior exits unless one side of the passageway is at least 50% open to the exterior and exit stairs are provided at both ends of the passageway, in which case no separation is required.

## DEAD-END CORRIDORS

Dead-end pockets in exit access corridors are undesirable and are most commonly limited to 20–50 ft (6–15 m) in length. For detailed dead-end corridor limitations, see page 301 for the International Building Code and page 307 for the National Building Code of Canada.



**DEAD-END CORRIDORS**

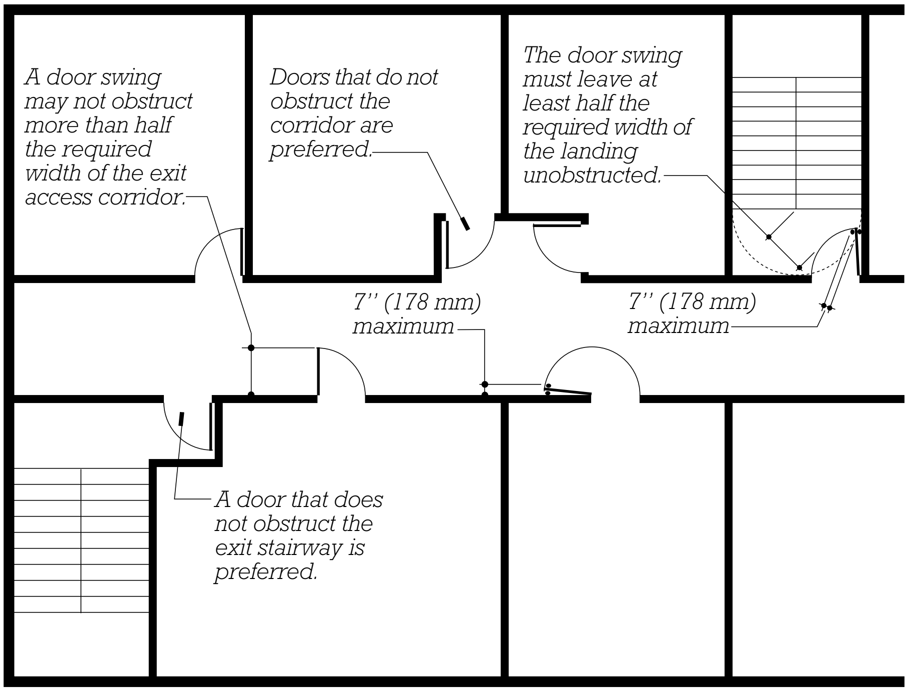
# THE EXIT ACCESS

## DOORS

In the majority of circumstances, doors forming part of an egress path must operate by swinging. Sliding doors or doors with other types of operation are permitted as egress doors within individual dwelling units, serving spaces with limited occupant loads, and in other unique circumstances. See the codes for details.

The International Building Code requires all doors serving an occupant load of 50 or more, or serving any Group H Hazardous Occupancy, to swing in the direction of egress travel. The National Building Code of Canada requires all doors serving exits, all doors serving F-1 High-Hazard Occupancies, and all exit access doors serving an occupant load greater than 60 to swing in the direction of egress travel.

Doorways must be arranged to minimize obstruction of egress pathways. The International Building Code limits door encroachment into required egress ways to not more than 7 in. (178 mm) when fully open and not more than one-half of the required egress width throughout the door swing. The National Building Code of Canada permits similar encroachments for egress doors in small buildings (see page 292): Ftully open doors may not encroach more than 100 mm (4 in.) into egress corridor pathways or 50 mm (2 in.) into other parts of the egress system; throughout their swing, doors may not reduce the required width of corridors and passages by more than one-half or of exit stairways by more than 750 mm (30 in.).



DOORS

Even when locked, doors along an exit path must open easily in the direction of egress travel. Doors in fire-resistance rated walls must themselves be fire-resistance rated, although usually to a value somewhat lower than the wall in which they are located.

Information on sizing of egress doorways may be found on page 301 for the International Building Code and on page 307 for the National Building Code of Canada.

## OTHER EXIT ACCESS REQUIREMENTS

The model building codes contain many additional provisions relating to illumination of exit access facilities, marking of exit paths, combustibility of finish materials in exit access corridors, alarm systems, door operation and hardware, and other safety concerns. Consult the appropriate code for details.

## EXITS

The exit is the portion of the means of egress following the exit access that is designed to provide a greater degree of protection to building occupants. Exits must be enclosed within fire-resisted rated assemblies, cannot be used for purposes other than egress, and must be continuous until they discharge from the building. In other words, once building occupants enter an exit stairway or exit passageway, they must be able to leave the building without passing through areas intended for other uses or providing lower levels of protection (with exceptions as noted later in this section, such as for lobbies and vestibules).

In most circumstances, each floor of a building must have at least two independent exits. Wherever more than one exit is required, the capacity of the exits should be balanced so that if one becomes unusable, those remaining are reasonably capable of accommodating the occupant load. Exit requirements unique to each model building code are discussed below.

### International Building Code

For most buildings, each floor or roof level with 500 or fewer occupants must have at least two independent exits. Levels with between 501 and 1000 occupants must have at least three such exits, and levels with more than 1000 occupants must have at least four. Where multiple exits are required, they must be arranged to meet the separation requirements described on page 267. For special requirements for additional exits in tall buildings, see page 291.

Certain Occupancies are permitted to have only one exit from a floor. For a floor at grade or the uppermost level of a basement below grade, one exit is permitted for the following:

- A, M, and U Occupancies with an occupant load not greater than 49 and travel distance to the exit not exceeding 75 ft (22.9 m)
- B, F, and S Occupancies with an occupant load not greater than 49 and travel distance to the exit not exceeding 75 ft (22.9 m); or, if the building is fully sprinklered, with travel distance to the exit not exceeding 100 ft (30 m)
- E Occupancies with an occupant load not greater than 49 and travel distance to the exit not exceeding 75 ft (22.9 m), except for day care occupancies, with an occupant load not greater than 10
- H-2 and H-3 Occupancies with an occupant load not greater than 3 and travel distance to the exit not exceeding 25 ft (7.6 m) or H-4 and H-5 Occupancies with an occupant load not greater than 10 and travel distance to the exit not exceeding 75 ft (22.9 m)
- I Occupancies with an occupant load not greater than 10 and travel distance to the exit not exceeding 75 ft (22.9 m)
- S Occupancies (not including parking) with an occupant load not greater than 29 and travel distance to the exit not exceeding 100 ft (30 m)

For second stories, one exit is permitted for the following:

- B, F, M, and S (not including parking) Occupancies with an occupant load not greater than 29 and travel distance to the exit not exceeding 75 ft (22.9 m)

Certain residential occupancy conditions are also permitted one exit:

- Any R-3 Occupancy building.
- Any first-floor or uppermost basement level R Occupancy with an occupant load not greater than 10 and travel distance to the exit not exceeding 75 ft (22.9 m).
- Second-story R-2 Occupancies with not more than four dwelling units and travel distance to the exit not exceeding 50 ft (15.2 m); this provision may be extended to the third floor when the building is provided with an NFPA 13 or 13R, but not 13D, sprinkler system. (See page 428 for more information on R-2 Occupancy sprinkler systems.)
- From within individual dwelling units in R-2 Occupancies, with an occupant load not exceeding 20, with NFPA 13 or 13R sprinkler systems.

Note that where single-exit floors are permitted by this code, common path of egress travel limitations, as described on page 268, do not apply.

## National Building Code of Canada

Most buildings must have at least two independent exits from each floor. Floors of one- or two-story buildings may have only one exit if they have not more than 60 occupants and do not exceed the floor area and travel distance limits in the table at right. In the case of B Care, Treatment, or Detention and C Residential Occupancies (other than dwelling units), such exits must open directly to the exterior, without enclosed stairways, not more than 1.5 m (5 ft) above the adjacent ground level.

Individual dwelling units within Residential Occupancies are permitted to have just one means of egress when:

- A single exit door leads directly to the exterior not more than 1.5 m (5 ft) above grade and
- The exit door is within one story of every floor level within the unit, or the uppermost floor of the unit opens to an exterior balcony that is not more than 6 m (20 ft) above grade

A-3 Open Air Assembly Occupancy tiers or balconies with between 1001 and 4000 occupants must have at least three exits, and those with more than 4000 occupants must have at least four exits.

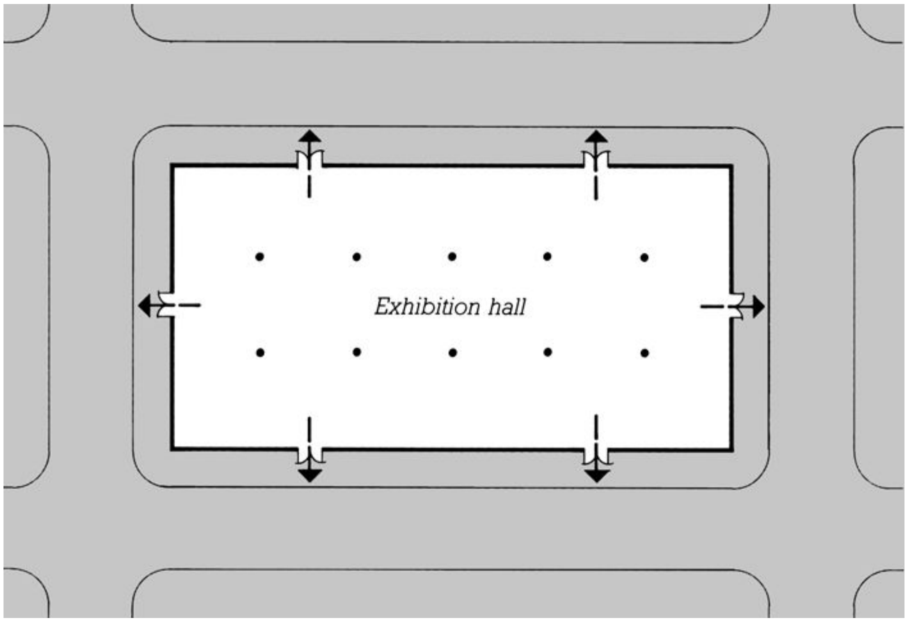
Wherever more than one exit is required, each individual exit may only count toward up to one-half of the total required egress capacity.

**NATIONAL BUILDING CODE OF CANADA: FLOORS WITH SINGLE EXITS**

| | *Unsprinklered* | | *Sprinklered* | |
|---|---|---|---|---|
| **Single-Exit Occupancies** | **Maximum Floor Area** | **Maximum Travel Distance** | **Maximum Floor Area** | **Maximum Travel Distance** |
| A: Assembly | 150 m$^2$ (1615 ft$^2$) | 15 m (49 ft) | 200 m$^2$ (2150 ft$^2$) | 25 m (82 ft) |
| B: Care, Treatment, or Detention | 75 m$^2$ (805 ft$^2$) | 10 m (33 ft) | 100 m$^2$ (1075 ft$^2$) | 25 m (82 ft) |
| C: Residential | 100 m$^2$ (1075 ft$^2$) | 15 m (49 ft) | 150 m$^2$ (1615 ft$^2$) | 25 m (82 ft) |
| D: Business and Personal Services | 200 m$^2$ (2150 ft$^2$) | 25 m (82 ft) | 300 m$^2$ (3330 ft$^2$) | 25 m (82 ft) |
| E: Mercantile | 150 m2 (1615 ft$^2$) | 15 m (49 ft) | 200 m$^2$ (2150 ft$^2$) | 25 m (82 ft) |
| F-2: Industrial, Medium-Hazard | 150 m$^2$ (1615 ft$^2$) | 10 m (33 ft) | 200 m$^2$ (2150 ft$^2$) | 25 m (82 ft) |
| F-3: Industrial, Low-Hazard | 200 m$^2$ (2150 ft$^2$) | 15 m (49 ft) | 300 m$^2$ (3330 ft$^2$) | 25 m (82 ft) |
| Occupied Roofs | Two exits required if occupant load is greater than 60 | | | |

## DIRECT EXIT

The simplest type of exit is a door opening directly from an interior room or space to the exterior, as might occur from an exhibition hall, theater, gymnasium, or classroom. Exit doors of this type do not normally need to have a fire-resistance rating.

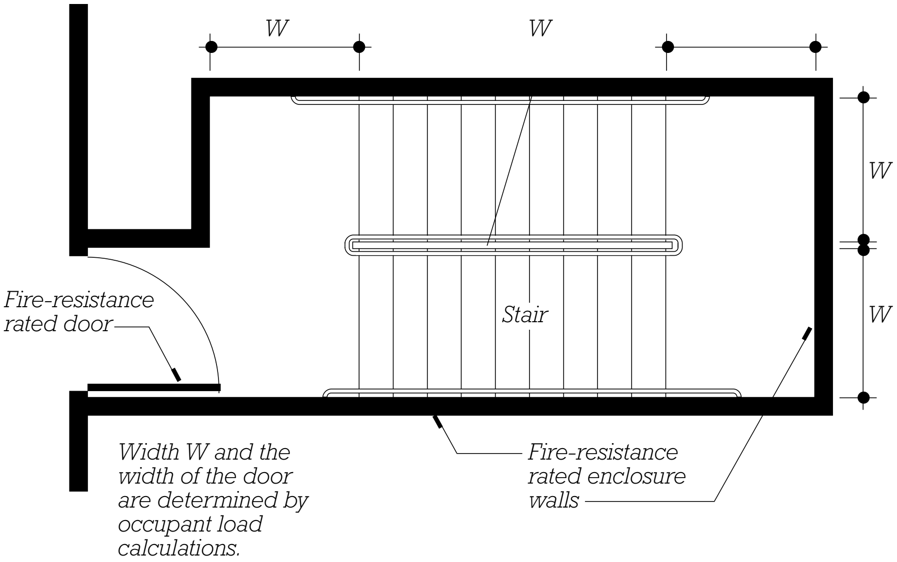


DIRECT EXITS

## EXIT STAIRWAYS

Enclosed stairways are the most common form of exit component. Minimum required widths for stairways and landings depend on the Occupancy and the number of occupants served. See pages 209–303 for the International Building Code and pages 305–309 for the National Building Code of Canada. Dimensions and typical designs for stairways and stair enclosures are provided on pages 315–325. For provisions allowing open (unenclosed) exit stairways, see the following text.

In general, escalators and elevators may not serve as required exits in place of stairways. However, both the International Building Code and the National Building Code of Canada permit elevators to serve as a means of egress for disabled persons. For more information, see Accessible Means of Egress on pages 282–283 and 286, respectively.



EXIT STAIRWAYS

### International Building Code

The International Building Code requires exit stairways serving four stories or more to be enclosed within 2-hour fire-resistance rated construction with 1½-hour self-closing doors opening from each floor into the stairway. Enclosures of stairways serving fewer than four floors may be of 1-hour rated construction, with 1-hour self-closing doors. However, exit enclosures penetrating floors with a fire-resistance rating of 2 hours or more must also be 2-hour rated, regardless of the number of stories served. Exit enclosure doors opening to the exterior are not required to be rated. Exit enclosures are not required for:

- Stairways not counted as a part of the required means of egress
- Exit stairways within dwelling or sleeping units of Group R-1, R-2, or R-3 Occupancies

- In other than Group H or I Occupancies, exit stairways connecting the floor level from which occupants leave the building to either the floor directly above or directly below and not serving an occupant load greater than 10
- In other than H or I Occupancies, a stairway serving only one adjacent floor and providing not more than 50% of the floor's required egress capacity, provided that these floors are not open to other floors in the building
- In a fully sprinklered building with other than H or I Occupancies, any stairways serving only the first and second floors of the building, provided that these floors are served by at least two independent exits and are not open to other floors
- Exit stairways in open parking garage structures or open arenas

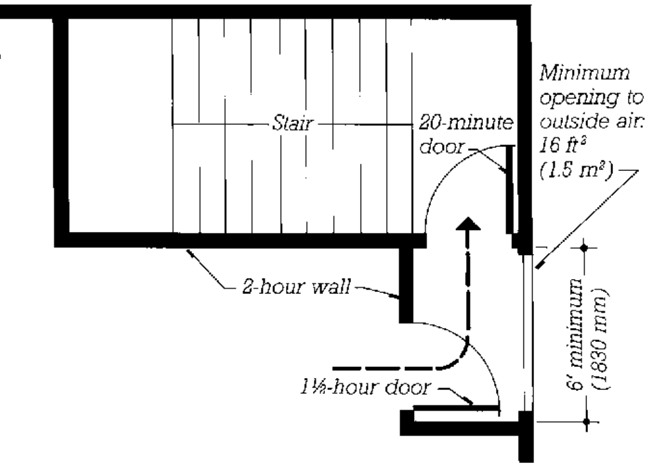
When designing with unenclosed exit stairways, be sure to check travel distance limits, as described on page 267, including travel along open stairs and continuing until an enclosed exit or exit from the building is reached.

The International Building Code requires doors in exit enclosures serving an occupant load of 50 or more to swing in the direction of egress travel. So-called scissor stairs, in which two intertwined stairways are contained within a single enclosure, are considered to be only a single exit stairway.

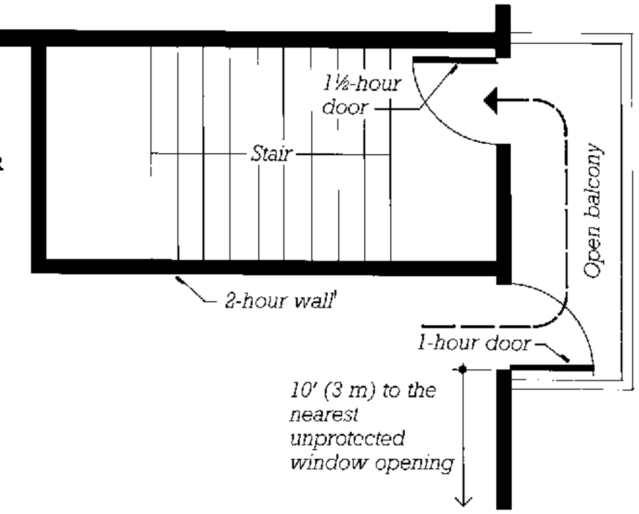
## National Building Code of Canada

The National Building Code of Canada requires the construction of an exit stairway enclosure to match the fire resistance of the floor assembly directly above that enclosure or, if there is no floor above, that of the floor below. However, the rating of the enclosure need never exceed 2 hours and it may never be less than ¾ hour. Doors opening into the stairway must be self-closing and in 2-hour enclosures must be 1½-hour rated; in 1½-hour enclosures, 1-hour rated; and in 1-hour or ¾-hour enclosures, ¾-hour rated.

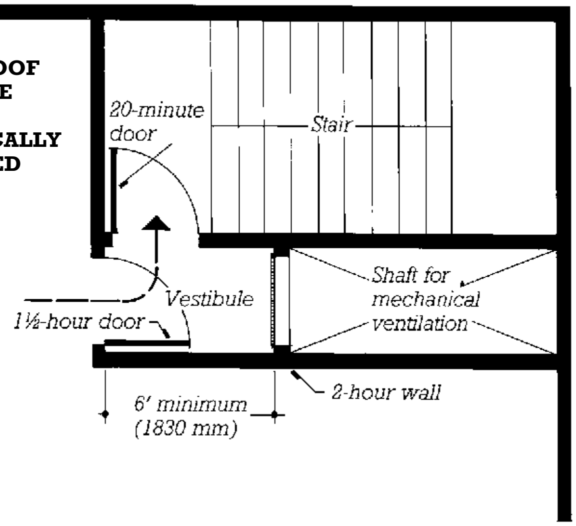
**SMOKEPROOF ENCLOSURE WITH A NATURALLY VENTILATED VESTIBULE**



**SMOKEPROOF ENCLOSURE WITH AN OPEN EXTERIOR BALCONY**



**SMOKEPROOF ENCLOSURE WITH A MECHANICALLY VENTILATED VESTIBULE**



## SMOKEPROOF ENCLOSURES

The model building codes require exit stair enclosures in tall buildings to be designed as *smokeproof enclosures* to provide a higher level of protection to occupants exiting from such buildings during a fire emergency. In the International Building Code, these requirements apply to high-rise buildings as well as to buildings with significant underground occupancy. The National Building Code of Canada has similar requirements, most commonly applicable to buildings with occupied floors more than 18 to 36 m (59 to 188 ft) above grade, depending on the type of Occupancy. For additional information about high-rise building requirements, see High-Rise and Underground Buildings, page 291, for the International Building Code and High Buildings, page 292, for the National Building Code of Canada.

Smokeproof enclosures are designed to protect exit stairways from the entry of smoke during a building fire. Naturally ventilated vestibules and open exterior balconies allow smoke on a fire-engaged floor to exhaust to the exterior before reaching the stairway. Vestibules may also rely on mechanical systems for smoke exhaust. See the accompanying illustrations. In fully sprinklered buildings, stairway enclosures may themselves be mechanically pressurized to deter smoke from entering the stairway, in which case intervening vestibules or balconies are not required (not illustrated).

A stairway in a smokeproof enclosure must normally discharge into a public way, an outdoor space having direct access to a public way, or an enclosed exit passageway. The International Building

Code also allows smokeproof exit enclosures to discharge through exit level open areas and vestibules, as described on page 280.

## EXTERIOR STAIRWAYS AND FIRE ESCAPES

Both model building codes permit the use of exterior stairways as part of the building egress system. When designing with exterior exit stairways, travel distance (page 267) is measured the same way as for an interior stairway, that is, up to the entrance to the stairway, but not including travel on the stairway itself.

In the International Building Code, a stairway is considered exterior when at least one side has a minimum open area of 35 sq ft (3.3 $m^2$) at each floor level. Exterior stairways are not permitted for I-2 Occupancies, for buildings taller than six stories in height, or for buildings with the highest occupied floor more than 75 ft (22.9 m) above the lowest ground level. Exterior stairways must be constructed with solid treads (as distinct from open gratings), and they must not allow the accumulation of standing water. Requirements for separation of exterior stairways from the building interior vary with the height of the building, the presence of a sprinkler system, the Occupancies involved, and the configuration of the egress system. See the code for details.

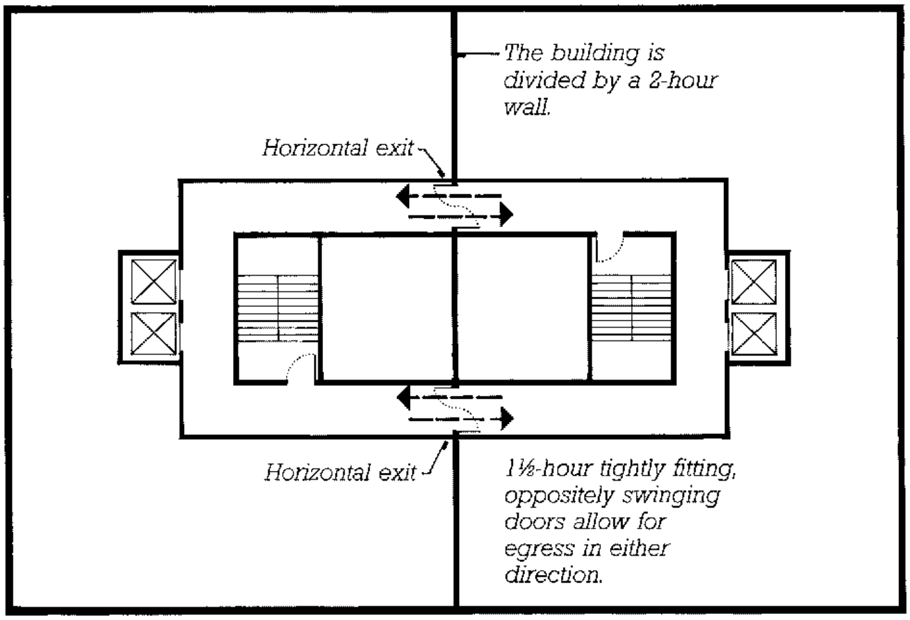
Traditional open metal fire escapes are not permitted as exits except in very limited circumstances. The International Building Code permits fire escapes as a second exit in existing buildings where it is impractical to construct a stair meeting current code requirements. Escape slides, rope ladders, escalators, and elevators cannot be counted as required exits. Fixed ladders are permitted as required exits only in certain mechanical spaces and industrial occupancies serving a limited number of able-bodied workers, and then the ladder may serve only as a second means of egress from the space.

In the National Building Code of Canada, treads and landings more than 10 m (33 ft) above grade must be protected from snow or ice accumulation. This code also permits fire escapes as a second exit in existing buildings where other forms of exit are impractical. Such fire escapes may serve up to two stories above ground, with B Treatment, Care, or Detention Occupancies, or up to five stories above ground, serving other occupancies.

## REFUGE AREAS AND HORIZONTAL EXITS

A *refuge area* is a protected area within a building or an adjacent building to which occupants can retreat—without reliance on stairways—to escape the danger of fire. Such areas are required in care facilities where, in the case of emergency, patients must be moved to safety while still in their beds, and in detention facilities, where it is not practical to allow occupants to exit from the building. Refuge areas are sometimes used in very tall buildings, allowing larger numbers of occupants to escape the immediate danger of fire more quickly than would be possible using exit stairways. They can also serve as a component of the means of egress between adjacent buildings.

In the International Building Code, I-2 Medical and Custodial Care and I-3 Detention and Security Occupancy floors must be subdivided into at least two distinct refuge areas wherever floors include sleeping units or treatment areas, or have an occupant load of 50 or more. Such areas are separated from surrounding spaces by smoke barriers (wall and floor assemblies resistant to the passage of smoke but not necessarily having a fire-resistance rating). Each refuge area must provide access to a second independent means of egress. In I-2 Occupancies, the refuge area occupant capacity is calculated as 15 sq ft (1.4 $m^2$) per ambulatory occupant and 30 sq ft (2.8 $m^2$) per nonambulatory occupant. Individual refuge areas cannot exceed 22,500 sq ft (2092 $m^2$) in area. In I-3 Occupancies, 6 sq ft (0.56 $m^2$) per person is required and the individual refuge area occupant capacity cannot exceed 200 persons. As an alternative to providing separate refuge areas in I-3 Occupancies, residents may be provided with direct exit access to a public way, separate building, or secured yard or court.



HORIZONTAL EXITS

In the National Building Code of Canada, B-2 Medical Treatment and B-3 Care Occupancy floors must be subdivided into two or more refuge areas wherever floors include sleeping or patient rooms for 10 or more patients or residents. Refuge areas are separated from adjacent spaces by wall and floor assemblies with a fire-resistance rating of 45 minutes to 1 hour. Each refuge area must provide access to a second independent means of egress. Occupant capacity is calculated as 1.5 $m^2$ (16 sq ft) per wheelchair occupant, 2.5 $m^2$ (27 sq ft) per bedridden occupant, and 0.5 $m^2$ (5.4 sq ft) per person for other occupants. Individual refuge areas cannot exceed 1000 $m^2$ (10,765 sq ft) in area. In addition, operating rooms, recovery rooms, delivery rooms, and intensive care units where patients cannot easily be moved must be separated from other areas by wall and floor assemblies with a 1-hour fire-resistance rating and protected from smoke infiltration by a dedicated mechanical air supply system.

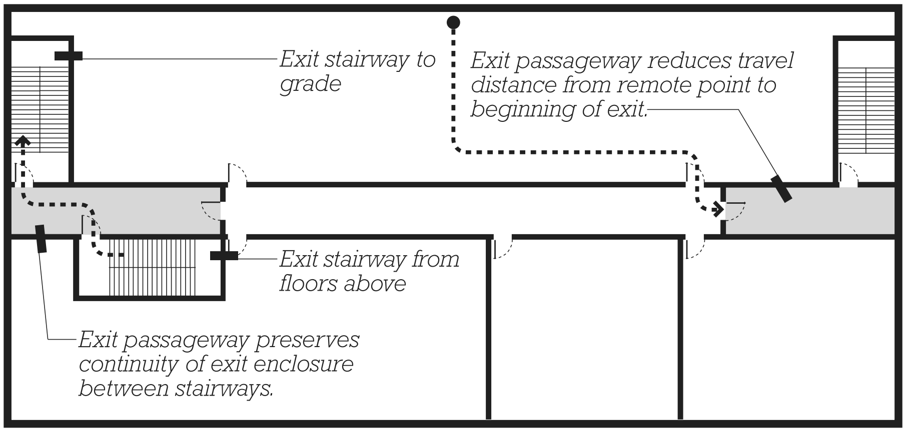
Both model codes also permit egress through fire walls to refuge areas in separate but adjacent buildings. Such *horizontal exits* are normally permitted to provide up to one-half of the required exit capacity of a story (or more in certain medical, care, and detention occupancies). The refuge area must have sufficient capacity to accommodate its own occupants plus the added occupants arriving through the horizontal exit, and it must have at least one additional independent means of egress. For more information on fire wall requirements, see page 375.

In other than the care, treatment, and detention Occupancies noted above, refuge area occupant capacity is calculated as 6 sq ft (0.6 $m^2$) per person in the International Building Code and as 0.5 $m^2$ (5.4 sq ft) per person in the National Building Code of Canada. Private spaces inaccessible to occupants arriving through the horizontal exit should not be included in these calculations.

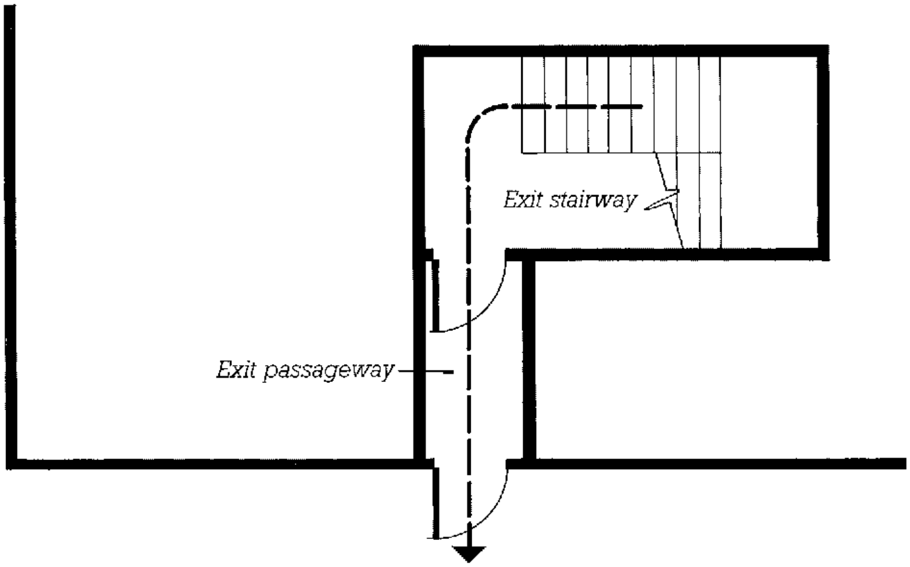
A horizontal exit may be designed to function for travel in one direction only, as in the case of a building that has one exit stairway and a horizontal exit to an adjoining building that has two or more exit stairways. In this case, the corridors and lobbies of the adjoining building serve as the refuge area for the first building. Or a horizontal exit may be designed to function for travel in both directions, as shown in the illustration on the previous page. In this case, the corridor on the left side of the building serves as an area of refuge for the occupants of the right side, and vice versa.

## EXIT PASSAGEWAYS

An *exit passageway* is a horizontal portion of the means of egress that is protected from fire in the same manner as an enclosed exit stair. An exit passageway has several uses: It may be used to preserve the continuity of enclosure for an exit stair whose location shifts as it descends through the building, to eliminate excessive travel distance within a floor, or to connect the bottom of an enclosed stairway to a remotely located exterior exit doorway. Exit passageways must meet the same width requirements as corridors, as tabulated on pages 299–303 and 305–309.



EXIT PASSAGEWAYS



EXIT DISCHARGE THROUGH AN EXIT PASSAGEWAY

# THE EXIT DISCHARGE

The exit discharge connects the exit to the public way or to some other place of safety. It can include both exterior and interior elements.

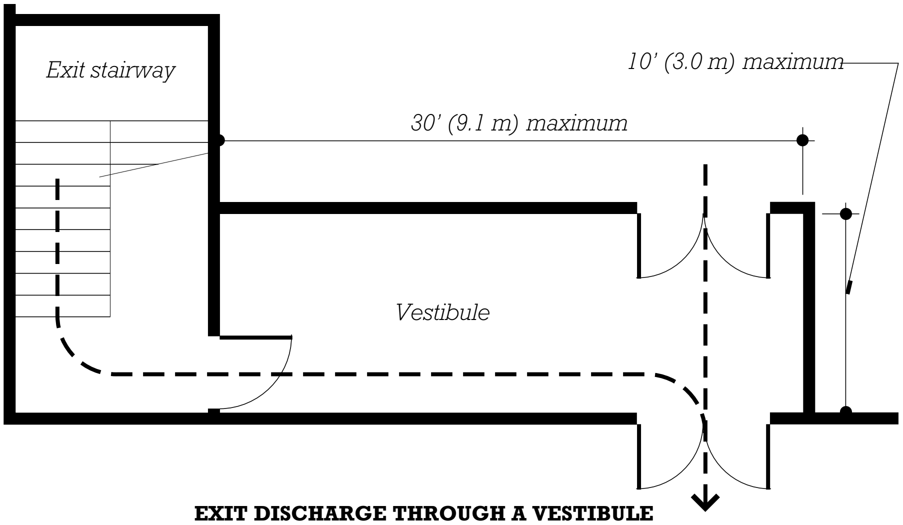
In the International Building Code, exterior stairways and ramps that are part of the exit discharge must be located at least 10 ft (3 m) from adjacent buildings and property lines. When courts or yards serving as part of the exit discharge are less than 10 ft (3.0 m) wide, building walls abutting the court must be 1-hour fire resistance rated, and openings in the walls ¾-hour rated, for a height of at least 10 ft (3.0 m) above the court level (except R-3 Occupancies and courts serving fewer than 10 occupants). Where access to a public way cannot be provided, exits may discharge to a dispersal area on the same property located at least 50 ft (15 m) from the building and providing at least 5 sq ft (0.46 m$^2$) of space per person.

## LOBBIES AND VESTIBULES

Both model codes permit some exits to discharge through interior areas in certain circumstances.

The International Building Code permits up to 50% of a building's required egress capacity to discharge through open areas or vestibules on the ground floor level of a building. For areas such as lobbies:

- The egress pathway must be readily identifiable.
- The entire floor level must be separated from levels below by construction with a fire-resistance rating at least equal to that required for the exit enclosure.
- The entire floor must be sprinklered, or unsprinklered portions must be separated from the exit discharge area by walls with the same fire-resistance rating as that required for the exit.



**EXIT DISCHARGE THROUGH A VESTIBULE**

Vestibules must be dedicated solely to egress, limited in dimension as indicated on the accompanying diagram, separated from levels below by construction with a fire-resistance rating equal to that required of the exit, and separated from the remainder of the building by the equivalent of ¾-hour fire-resistance rated partitions or glazing.

The National Building Code of Canada permits no more than one exit to pass through a lobby, provided that:

- The lobby floor is not more than 4.5 m (148 ft) above grade
- The path of travel through the lobby to the exterior does not exceed 15 m (49 ft)
- The lobby does not provide direct access to B-3 Care, C Residential, or F Industrial Occupancies
- The lobby is not part of an interconnected floor space (see page 373) except as permitted for exit stairs
- The remainder of the exit is separated from the lobby by a standard exit enclosure
- The lobby is separated from other areas by assemblies with the same rating required for an exit enclosure, except that, if the floor is fully sprinklered, separations do not require a fire-resistance rating

## REVOLVING DOORS

Revolving doors are permitted as exit discharge components, provided that they are constructed so as to allow free passage in a panic situation by collapsing under pressure into a book-fold position.

The International Building Code limits revolving doors to a capacity of 50 persons per door and, in total, to no more than half the required exit capacity of a building. There must be a swinging door in the same wall and within 10 ft (3 m) of the revolving door, and revolving doors may not be located within 10 ft (3 m) of the foot or top of a stair or escalator.

The National Building Code of Canada limits the exit capacity of each revolving door to 45 persons and permits revolving doors to serve as egress for ground-floor occupants only. Swinging doors must be located adjacent to revolving doors, and revolving doors must not be located at the foot of a stairway. Alternatively, specially designed electrically powered revolving doors are permitted for higher occupant capacities and without adjacent swinging doors.

# ACCESSIBLE ROUTES

The goal of accessibility legislation in both the United States and Canada is to provide people with physical limitations full access to nearly all types of buildings, including, for example, government buildings, schools, houses of worship, retail establishments, places of business, public and private transportation facilities, bars, restaurants, hotels, housing, places of entertainment and culture, recreational facilities, and places of work. Buildings and their surroundings must provide continuous, unobstructed routes by which physically disabled persons can park their vehicles or disembark from public transportation, approach the building, enter, reach virtually any point in the building, and gain access to the same amenities and activities available to others, such as retail counters, ticket windows, drinking fountains, toilet and washroom fixtures, public telephones, and spectator seating.

This section summarizes accessibility requirements of the two model building codes as they affect the form and organization of buildings. It does not address all technical requirements or occupancy circumstances addressed by these codes or the requirements of other accessibility regulations that may be enacted at provincial, state, or national levels. Be sure to consult the building code and other regulations applicable to your project as your building design progresses.

## THE INTERNATIONAL BUILDING CODE

In the International Building Code, most buildings and spaces are required to be made accessible for persons with physical disabilities. Exceptions include the following:

- Detached one- and two-family dwellings
- Most Occupancy Group U Utility and Miscellaneous buildings
- R-1 Occupancy hotel and motel buildings when owner-occupied and containing not more than five sleeping units
- Certain common-use portions of detention and correctional facilities
- Single-occupant structures, such as toll booths, accessed primarily by underground tunnels or overhead walkways
- Raised areas, such as guard towers or observation galleries, used for security or life safety
- Equipment spaces, service spaces, and nonoccupiable limited-access spaces

Accessibility requirements for employee work areas are generally limited to common use circulation paths such that persons with disabilities can enter and exit the work area. Where an exempt residential structure includes day care or live/work facilities, these nonresidential portions of the structure must be made accessible.

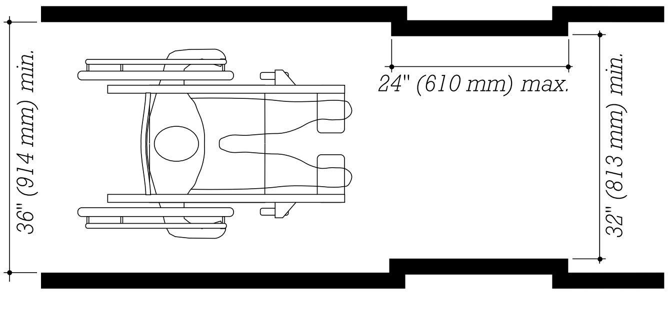
Where a building is required to be accessible, its main entrance and not less than 60% of all of its public entrances must be accessible, and accessible routes must lead to each portion of the building. If only one accessible route is provided within a building, it may not pass through kitchens, storage rooms, restrooms, or other such ancillary spaces. However, in dwelling units, a single accessible route may pass through a kitchen or storage room.

In multilevel buildings, an accessible route must connect each level, including mezzanines, except:

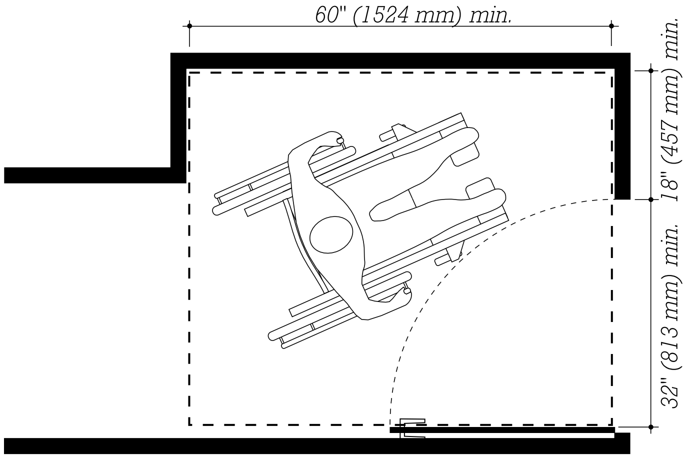
- Floors and mezzanines above or below accessible levels, not more than 3000 sq ft (280 m$^2$) in area, unless such floors contain offices of health care providers, passenger transportation facilities, or five or more M Occupancy tenant spaces
- Levels themselves not required to be accessible
- In two-story buildings, a single story with an occupant load of five or less and not containing public use space

Key dimensional criteria in the design of accessible routes include the following:

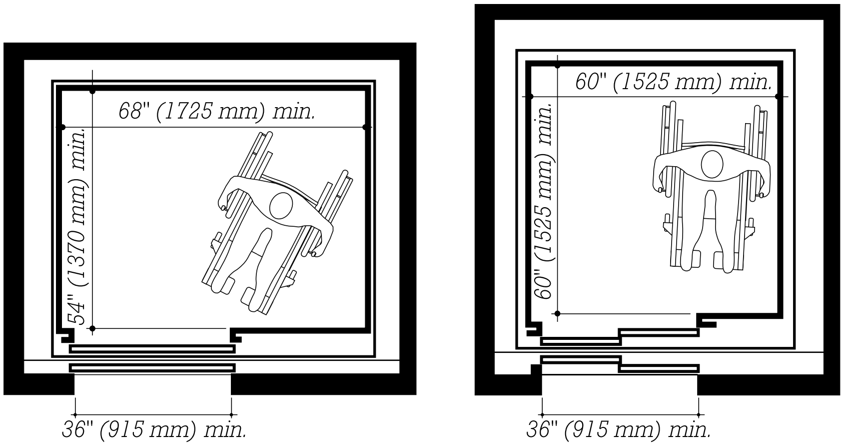
- Corridors,passages,anddoorways without doors must be at least 36 in. (915 mm) wide. Projections not more than 24 in. (610 mm) in length, and spaced at least 48 in. (1220 mm) apart, may reduce the passage width to not less than 32 in. (815 mm).
- Walking surfaces, except for ramps, may not be sloped greater than 1:20.
- Doorway openings must have a minimum 32-in. (815-mm) clear width.



INTERNATIONAL BUILDING CODE ACCESSIBLE CORRIDOR



**INTERNATIONAL BUILDING CODE EXAMPLE OF AN ACCESSIBLE DOORWAY AND APPROACH**



**INTERNATIONAL BUILDING CODE AND NATIONAL BUILDING CODE OF CANADA EXAMPLE ACCESSIBLE ELEVATORS**

- Latchside clearance for manually operated doors varies from 12 in. (305 mm) to 42 in. (1065 mm), depending on the manner in which the door is approached. When directly approaching a door opening on its pull side, 18 in. (445 mm) is required.
- The minimum diameter of a wheelchair turning circle is 60 in. (1525 mm).
- Ramps may not slope greater than 1:12, must have a minimum clear width of 36 in. (915 mm) between handrails, and may not rise more than 30 in. (760 mm) between landings. Landings must be not less than 60 in. (1525 mm) in length.

Elevator car minimum clear inside dimensions vary with the size and position of the elevator car door:

- With a 36-in. (915-mm) clear door opening in any location: 60 in. (1525 mm) wide by 60 in. (1525 mm) deep or 54 in. (1370 mm) wide by 80 in. (2030 mm) deep
- With a 36-in. (915-mm) clear door opening, offset to one side: 68 in. (1725 mm) wide by 51 in. (1295 mm) deep
- With a 42-in. (1065-mm) clear door opening, centered: 80 in. (2030 mm) wide by 51 in. (1295 mm) deep

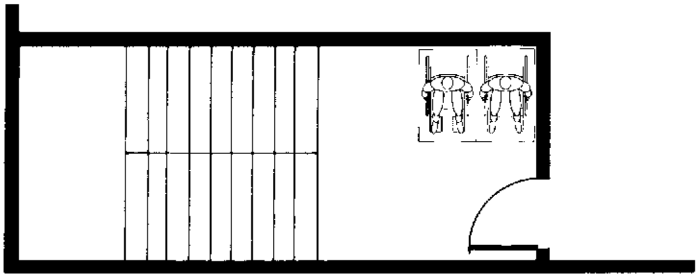
Though not strictly speaking an accessibility requirement, where one or more elevators are provided in a building with floors four or more stories above or below grade-level access, the International Building Code requires that at least one elevator serving all stories be large enough to accommodate a medical stretcher 24 in. (610 mm) wide and 84 in. (2134 mm) long and its attendants. The code does not specify minimum car dimensions that satisfy this requirement. For preliminary design purposes, the following may be considered one example of acceptable minimum size:

- With a 42-in. (1065-mm) clear door opening, offset to one side: 80 in. (2032 mm) deep by 54 in. (1372 mm) wide

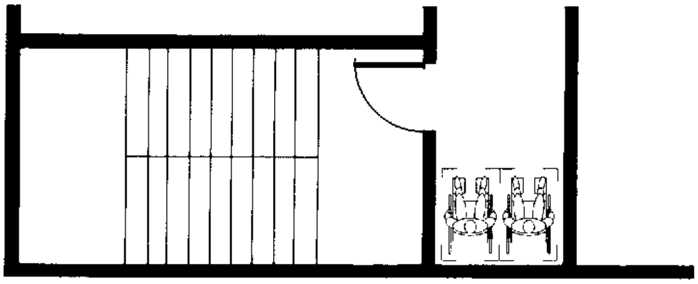
## Accessible Means of Egress

Wherever spaces are required to be accessible, at least one accessible means of egress (exit route) must also be provided. Where two or more conventional means of egress are required from any area, there must be at least two accessible means of egress. Such means of egress may include level accessible routes, accessible ramps, horizontal exits, areas of refuge, and appropriately designed stairways or elevators. In certain limited circumstances, platform lifts are also permitted to form part of an accessible means of egress.

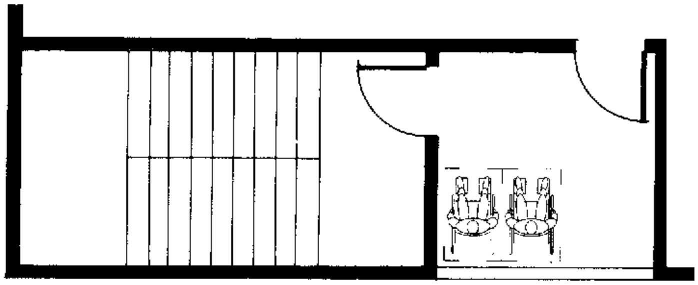
Most buildings with accessible floors above or below grade rely on egress stairways as part of the required accessible means of egress. These stairways must be at least 48 in. (1219 mm) in clear dimension between the handrails, meaning that the overall width of the stair must be approximately



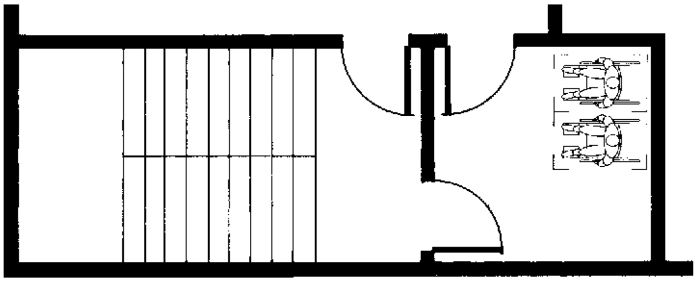
AREA OF REFUGE ON AN ENLARGED STAIRWAY LANDING



AREA OF REFUGE IN A 1-HOUR CORRIDOR



AREA OF REFUGE ON AN OUTDOOR BALCONY



AREA OF REFUGE IN A STAIRWAY VESTIBULE

56 in. (1400 mm), unless the building is fully sprinklered or the stairway is accessed from a horizontal exit. These stairways must also be provided with an area of refuge (see below) unless the building is fully sprinklered, the stairway is accessed from a horizontal exit, or the stairway serves an open parking garage or an R-2 Occupancy. Both enclosed and open stairways are permitted.

In buildings with accessible floors four or more stories above or below grade (for example, a five-story building), at least one accessible means of egress must consist of an elevator with a secure power supply. Alternatively, in a fully sprinklered building, floors above ground level may be served by horizontal exits (page 278) instead of an elevator. Fully sprinklered sports stadiums or other structures with accessible ramps serving each level are also exempt from this requirement. Where elevators are used, they must be provided with an area of refuge (see below) unless the building is fully sprinklered, the elevator is accessed from a horizontal exit, the elevator itself does not require an enclosed shaft, or the elevator serves an open parking garage.

Where required, an area of refuge must have direct access to the stairway or elevator it serves. It must be clearly identified with visual and tactile signage within the enclosure, protected from smoke and fire, provided with instructions for use, and provided with two-way electronic communications with the primary entry point of the building.

Areas of refuge may be constructed in a variety of ways: as enlarged floor-level landings within a stairway enclosure, areas within a rated corridor, outdoor balconies leading to an exit stairway, enclosed vestibules, or elevator lobbies constructed as smokeproof enclosures. A wheelchair space 30 × 48 in. (760 × 1220 mm) must be provided for every 200 occupants on each floor. These refuge spaces must not encroach into the required egress paths, and where multiple spaces are required, wheelchairs cannot be stacked more than two deep.

### Accessible Dwelling and Sleeping Units

In the International Building Code, accessibility requirements for sleeping and dwelling units apply to some extent to the following residential occupancies:

- Hotels and motels
- Apartment buildings and condominiums

- Nursing homes and assisted living facilities
- Boardinghouses, residential hotels, and motels
- Hospices and homeless shelters
- Corporate housing, dormitories, and migrant worker housing
- Seasonal vacation units and time-share units
- Residential structures comprised of four or more dwelling or sleeping units

Where accessibility requirements apply, dwelling or sleeping units must achieve one of three levels of accessibility. *Accessible units* are the most fully accessible. These units must meet all clear space and maneuverability requirements for wheelchair navigation and provide fully accessible work surfaces, fixtures, and equipment. *Type A units* must meet the same wheelchair clear space and maneuverability requirements as Accessible units. But other elements, such as special-height work surfaces and toilet room grab bars, are not required in this unit type as long as provision is made for their installation at a later date. *Type B units* provide the lowest level of accessibility. Wheelchair maneuverability requirements are less stringent, and some parts of units (for example, sunken living rooms or mezzanine-level bedrooms) need not be accessible.

| Occupancy | Minimum Number of Accessible Units |
|---|---|
| Group I-1 supervised residential facilities | 4%, but not less than 1 |
| Group I-2 nursing homes | 50%, but not less than 1 |
| Group I-2 hospitals and rehabilitation facilities | 10%, but not less than 1 |
| Group I-2 hospitals and rehabilitation facilities specializing in the treatment of patients with impaired mobility | 100% |
| Group I-3 detention and security facilities | 2%, but not less than 1 |
| Group R-1 hotels and motels, and Group R-2 boardinghouses, dormitories, fraternity houses, sorority houses, and any other facilities constructed with federal government funding | |
| With 1 to 25 units total | 1 |
| With 26 to 50 units total | 2 |
| With 51 to 75 units total | 4 |
| With 76 to 100 units total | 5 |
| With 101 to 150 units total | 7 |
| With 151 to 200 units total | 8 |
| With more than 200 units total | Approximately 3%; see the code for exact numbers |
| Group R-2 apartment houses and condominiums constructed without federal goverment funding, monasteries, and convents | None (see Type A unit requirements in the text) |
| Group R-3 one- and two-family residences and townhouses | None |
| Group R-4 assisted living facilities | 1 |

**Accessible Units:** For Accessible unit requirements, see the table on this page. For Occupancy Group R-1, requirements should be based on the total number of sleeping or dwelling units on a site, even when these units are contained in multiple detached buildings.

**Type A Units:** Group R-2 Residential buildings not required to provide Accessible units are subject to Type A unit requirements. This includes apartment houses constructed without federal government funding, monasteries, and convents. When they contain more than 20 dwelling or sleeping units, at least 2% but never less than one unit in these building types must be Type A.

**Type B Units:** In the following occupancy type buildings, where one building or multiple attached buildings contain four or more dwelling or sleeping units combined, all such units that are not Accessible or Type A must meet the requirements of at least Type B units: Groups I-1, I-2, R-2, R-3, and R-4.

This requirement also applies to Group R-1 hotels and motels to the extent that units in these buildings are occupied as permanent or semipermanent residences rather than as transitory accommodations. For example, where rooms in a hotel or motel are conventionally let out to overnight or short-term guests, Type B unit requirements do not apply. However, where such units may be used for extended-stay housing or as seasonal vacation units, they are considered occupied as residences, and compliance with Type B unit requirements is mandatory. Any sleeping accommodation occupied continuously for more than 30 days should be considered occupied as a residence. In addition, accommodations occupied for shorter periods may at times fall into this category when the nature of the occupancy, terms of payment, amenities provided, and other such factors are considered.

Where residential buildings do not have elevator service to all floors, or where site impracticality limits accessibility, a reduction in the number of required Type A or B units may be permitted. See the code for details.

### Additional Accessibility Information

Other aspects of design for the physically disabled are addressed elsewhere in this book: For accessible wheelchair space requirements in assembly seating areas, see page 290; for accessibility requirements for toilet and bathing facilities, see page 196; and for accessible parking requirements, see pages 334–335.

## BARRIER-FREE DESIGN IN THE NATIONAL BUILDING CODE OF CANADA

The National Building Code of Canada requires all buildings to be barrier-free except:

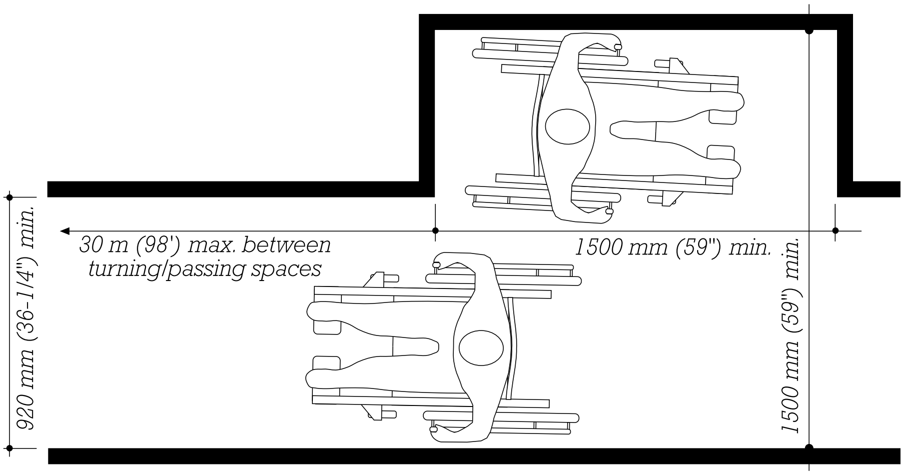
- Single-family residences, including detached and semi-detached houses, duplexes, triplexes, townhouses, row houses, boardinghouses, and secondary suites in one- or two-family houses
- Buildings with Group F-1 High-Hazard Industrial as their principal Occupancy
- Buildings not intended to be occupied daily or full-time, such as automatic telephone exchanges, pump houses, and electrical substations

Where a building is required to be barrier-free, its principal entrance, and not less than one-half of all of its pedestrian entrances, must be barrier-free. Where barrier-free access is required, barrier-free paths of travel must be provided throughout entrance stories and other normally occupied floor areas served by passenger elevators or other accessible means. Where escalators provide public access to multiple levels, alternative barrier-free means of access must be provided. Barrier-free paths of travel to the following locations are not required:

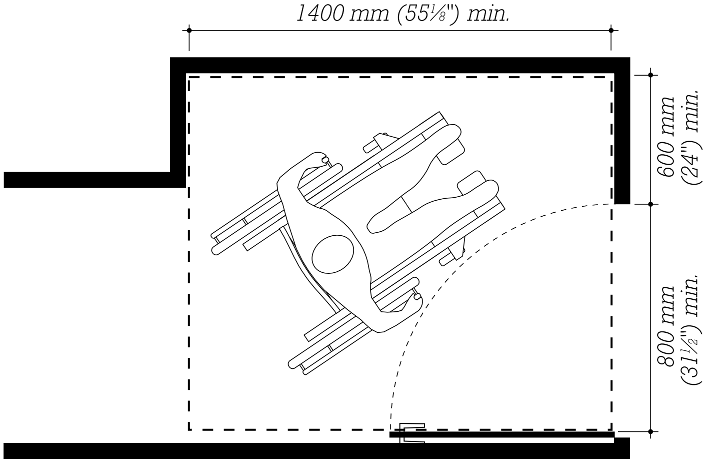
- Building service areas, crawlspaces, attics, rooftops, janitor's rooms, elevator machine rooms
- Floor levels not served by a passenger elevator, passenger-elevating device, escalator, or moving walk
- Mezzanines not served by passenger elevators or other accessible means
- Portions of fixed-seating floor areas within assembly occupancies not part of the path of travel to designated wheelchair spaces
- Portions of residential occupancy suites not at the entrance level
- Sunken or raised portions of floor areas not at the same level as the entrance level, provided that similar accessible amenities are provided at the entrance level
- F-1 High Hazard Industrial Occupancy areas

Key dimensional criteria in the design of barrier-free routes include the following:

- Corridors, passages, and doorways without doors must be at least 920 mm (36¼ in.) wide. Barrier-free paths longer than 30 m (98 ft) must provide a passing/turning space not less than 1500 mm (59 in.) square at intervals not exceeding 30 m (98 ft).
- Walking surfaces, except for ramps, may not be sloped greater than 1:20.
- Doorway openings must have a minimum 800-mm (31½-in.) clear width.
- Latch-side clearance for manually operated doors is 600 mm (24 in.) for doors swinging toward the approach side and 300 mm (12 in.) for doors swinging away from the approach side.
- The minimum diameter of a wheelchair turning circle is 1500 mm (59 in.).



NATIONAL BUILDING CODE OF CANADA BARRIER-FREE CORRIDOR



**NATIONAL BUILDING CODE OF CANADA EXAMPLE OF A BARRIER-FREE DOORWAY AND APPROACH**

- Ramps may not slope greater than 1:12, must have a minimum clear width of 870 mm (34¼ in.) between handrails, and may not exceed a horizontal distance of 9 m (29 ft 6 in.) between landings. Landings at the top and bottom of ramps must be not less than 1500 mm (59 in.) square. At intermediate points within the ramp, landings must be at least as wide as the ramp and not less than 1200 mm (48 in.) in length.

Elevator car minimum clear inside dimensions are identical to the requirements of the International Building Code and are repeated here for convenience. Minimum size requirements vary with the size and position of the elevator car door (see the illustrations on page 282):

- With a 915-mm (36-in.) clear door opening in any location: 1525 mm (60 in.) deep by 1525 mm (60 in.) wide or 2030 mm (80 in.) deep by 1370 mm (54 in.) wide
- With a 915-mm (36-in.) clear door opening, offset to one side: 1295 mm (51 in.) deep by 1725 mm (68 in.) wide
- With a 1065-mm (42-in.) clear door opening, centered: 1295 mm (51 in.) deep by 2030 mm (80 in.) wide

Though not strictly speaking a requirement for barrier-free access, where one or more elevators are provided in a building, the National Building Code of Canada also requires that at least one elevator serving all stories be large enough to accommodate a medical stretcher 610 mm (24 in.) wide and 2010 mm (79 in.) long and its attendants. The code does not specify minimum car dimensions that satisfy this requirement but does provide the following examples of recommended configurations:

- An elevator car with minimum clear interior dimensions of 2032 mm (80 in.) by 1295 mm (51 in.), with a 1067-mm (42-in.) clear door opening offset to one side of the 2032-mm side
- An elevator car with minimum clear interior dimensions of 2032 mm (80 in.) by 1295 mm (51 in.), with a 915-mm (36-in.) clear door opening on the 1295-mm side of the car

## Barrier-Free Egress

In the National Building Code of Canada, every accessible floor above or below the ground entrance level that is not sprinklered throughout must include at least one of the following provisions for the temporary refuge or rescue of occupants requiring assistance.

Elevator service meeting the requirements for firefighter use may be provided. Elevator entrances must be protected by 1-hour or 45-minute rated vestibules or corridors separating the entrances from surrounding floor areas. If the building is four or more stories in height, the elevator hoistway must be provided with smoke protection as well.

Such floors may be divided into at least two separate areas of refuge by 1-hour or 45-minute rated fire separation walls. Travel distance from any point on the floor to a doorway leading to a separate refuge area may not exceed the limits in the table on page 306. The minimum size of such areas should be based on the number of occupants served, calculated according to the guidelines provided on page 278.

In residential occupancies, exterior balconies serving each suite or floor area may be provided. Such balconies must not be less than 1.5 m (59 in.) in depth, and must provide not less than 1.5 m$^2$ (16.1 sq ft) of area for each nonambulatory occupant and 0.5 m$^2$ (5.4 sq ft) for each ambulatory occupant.

If site grading permits, this requirement may also be met by providing an exterior exit at ground level or a ramp leading to ground level.

## Additional Information on Barrier-Free Design

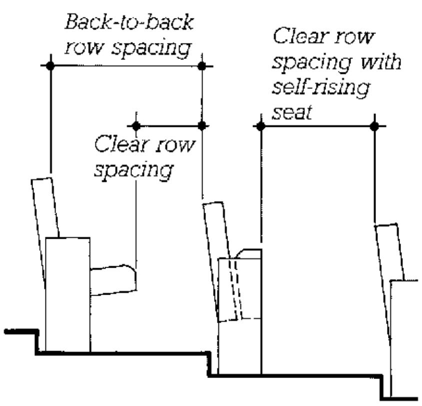
Other aspects of barrier-free design are addressed elsewhere in this book: For wheelchair space requirements in assembly seating areas, see page 290; for accessibility requirements for toilet and bathing facilities, see page 198; and for accessible parking requirements, see pages 334–335.

# EGRESS FROM AUDITORIUMS, CONCERT HALLS, AND THEATERS

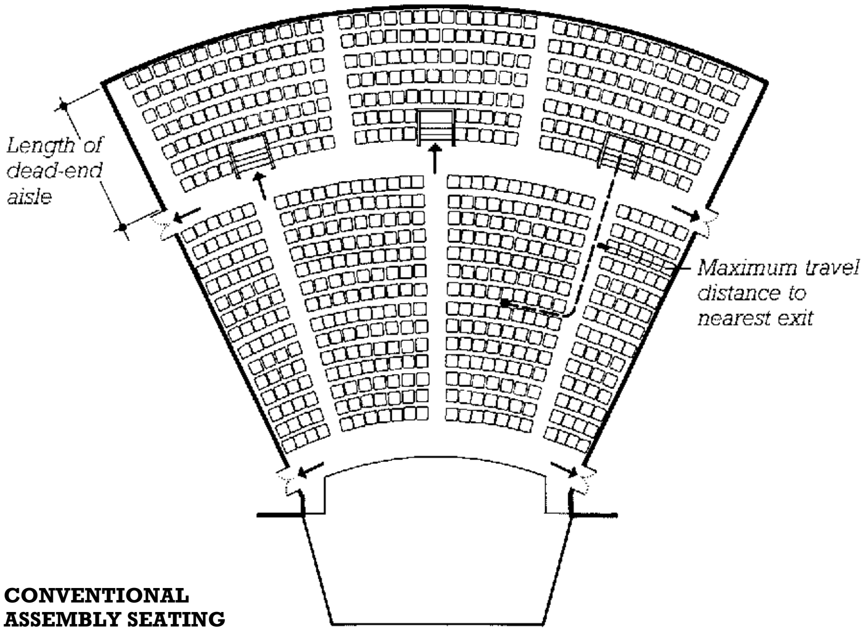
Assembly rooms, with their intense concentration of occupants, require special egress provisions to protect life safety. Two approaches to fixed seating arrangements are possible: In *conventional seating*, the length of seating rows is more limited, and a network of broad aisles is laid out to conduct the audience to a relatively small number of exits. In *continental seating*, longer rows of seating are permitted. Rows must be spaced farther apart, and more exit doors must be provided. The International Building Code and the National Building Code of Canada permit both approaches to assembly seating, although in a single consolidated set of egress requirements applicable to both types.

In the International Building Code, where assembly spaces serve more than 300 occupants (including A Occupancies and accessory assembly spaces in E Occupancies), the main exit of the building must provide egress capacity for at least half of the assembly occupant load. Each assembly space level having an occupant load greater than 300 must also provide access to both the main exit and alternative exits, also with an aggregate capacity equal to at least one-half the required exit capacity for that level. For A Occupancies, the main exit must front a public way. Alternatively, assembly spaces may be designed without a defined main exit, where multiple exits are distributed around the perimeter of the building. Interior balconies, galleries, and press boxes with occupant loads of 50 or more must also be provided with two remote means of egress, at least one of which leads directly to an exit.

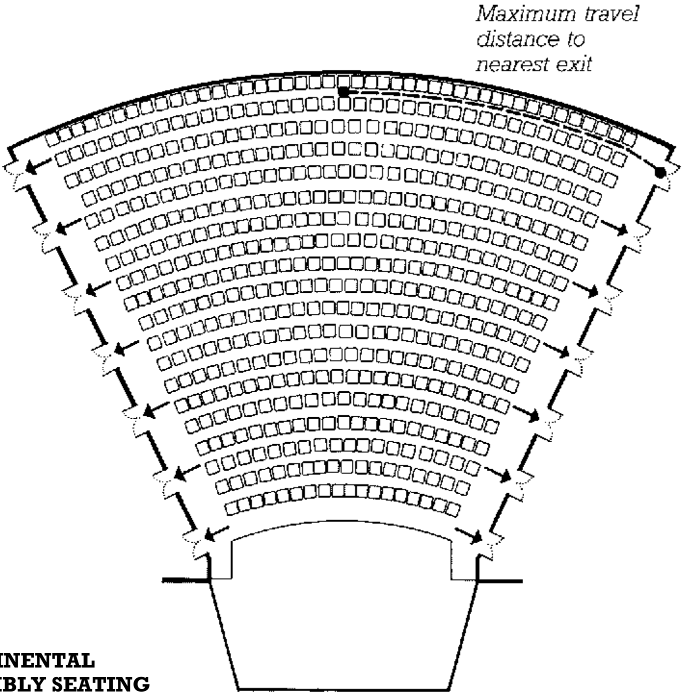
See the table on the following pages for egress width requirements for assembly seating areas in both model building codes. In the table, *clear row spacing* refers to the spacing between rows, as illustrated in the diagram on this page. In the International Building Code, assembly spaces designed with special smoke control provisions are permitted reductions in seating row and aisle width, and increases in travel distances, particularly for spaces with larger occupant loads. Consult the code for details.



**ROW SPACING**



**CONVENTIONAL ASSEMBLY SEATING**



**CONTINENTAL ASSEMBLY SEATING**

| | Seating | Aisles |
|---|---|---|
| **International Building Code** | For a row with egress at both ends:<br>Maximum row length: 100 seats<br>Minimum clear row spacing: 12" (305 mm) plus 0.3" (7.6 mm) for every seat above 14<br>For a row with egress at one end only:<br>Maximum length: Limited by common path of egress travel<br>Minimum clear row spacing: 12" (305 mm) plus 0.6" (15.3 mm) for every seat above 7<br>In all cases, maximum required clear row spacing is 22" (559 mm). | Aisle width:<br>Minimum: 30" (762 mm) for aisles serving not more than 14 seats; 36" (914 mm) for aisles serving seating on one side, or not more than 50 seats on two sides; 42" (1067 mm) for aisles serving more than 50 seats on two sides<br>For occupant load: Not less than 0.2" (5.1 mm) per person for aisles sloped not more than 1:12, or 0.22" (5.6 mm) per person for aisles with greater slopes<br>Aisles providing egress at only one end may vary in width; aisles with egress at both ends must be uniform in width.<br>Longest dead-end aisle: 20' (6 m), unless seats served by a dead-end aisle are within no more than 24 seats of another aisle and minimum clear row spacing is as required for rows with egress on one end only<br>Aisle termination: Cross-aisles sized the same as above, considering combined capacity of all converging aisles<br>Maximum slope of aisle: 1:8 |
| **National Building Code of Canada** | Continental seating:<br>Maximum row length: 100 seats, with exit doorways provided at the end of each row, each doorway serving not more than three rows<br>Minimum clear row spacing: 400 mm (15.8")<br>Conventional seating:<br>Maximum row length: 7 seats with backs, or 20 seats without backs between any seat and an aisle<br>Minimum clear row spacing: 400 mm (15.8") | Aisle width:<br>Minimum: 750 mm (29.5") when serving not more than 60 seats; 900 mm (35.4") when serving seats on only one side of the aisle; 1100 mm (43.3") when serving 60 or more seats on two sides<br>Increase the minimum aisle widths stated above in the direction of egress travel by 25 mm (1") for each meter of length from the aisle's most remote point.<br>Aisles providing egress at only one end may vary in width; aisles with egress at both ends must be uniform in width.<br>Longest dead-end aisle: 6 m (19'-8")<br>Aisle termination: At cross-aisles, foyers, or exits with a width equal to the width of the widest aisle served, plus 50% of the width of the remaining aisles served<br>Maximum slope of aisle: 1:8 |

| **Aisle Stairs and Handrails** | **Egress Travel Limits (pp. 267–268)** |
|---|---|
| Minimum tread depth: 11" (279 mm)<br>Maximum riser height: 8" (203 mm); up to 9" (229 mm) permitted where necessitated by slope of adjacent seating<br>Minimum riser height: 4" (102 mm)<br>Minimum stair width: 36" (914 mm) for stairs serving seating on one side or not more than 50 seats on two sides, or 48" (1219 mm) for stairs serving more than 50 seats on two sides.<br>Stairs width for occupant load: Not less than 0.3" (7.6 mm) per person for stairs with risers not greater than 7" (178 mm); add an additional 0.005" (0.13 mm) per person for each additional 0.1" (2.5 mm) of riser height; where egress requires stair descent and no handrail is within 30" (762 mm) to either side, add an additional 0.005" (0.13 mm) per person.<br>Handrails required: All stairs; ramped aisles sloped more than 1:15<br>Handrails subdividing stairs or aisles serving seats on both sides may be discontinuous to allow aisle access; the minimum space between the handrail and adjacent seating is 23" (574 mm).<br>Minimum tread depth: 11" (279 mm)<br>Maximum riser height: 8" (203 mm); up to 9" (229 mm) permitted where necessitated by slope of adjacent seating<br>Minimum riser height: 4" (102 mm) | Maximum travel distance to an exit:<br>Unsprinklered: 200' (61 m)<br>Sprinklered: 250' (76 m)<br>In open air seating: 400' (122 m) to the exterior, or unlimited in Type I or II Construction<br>Maximum common path of egress travel:<br>Areas serving not more than 50 occupants: 75' (23 m)<br>Other areas: 30' (9 m) |
| Minimum tread depth: 230 mm (9.1")<br>Maximum riser height: 200 mm (7.9")<br>Minimum riser height: 110 mm (4.3")<br>Stair width: See page 291.<br>Handrails: No special requirements | Maximum travel distance to an exit:<br>Unsprinklered and sprinklered: 45 m (148') |

## WHEELCHAIR SEATING CAPACITY

In Assembly spaces, minimum accommodations for wheelchair seating must be provided according to the adjacent table.

The International Building Code requires that wheelchair spaces within luxury suites or boxes be allocated within individual suites, and across all suites, according to the same rates. For example, a luxury box with 4 seats requires at least one wheelchair space, a box with 40 seats requires two such spaces, and 10 boxes of 3 seats each (30 seats total) require at least two wheelchair spaces among them.

| Code | Total Capacity | Wheelchair Seating |
|---|---|---|
| International Building Code | 4–25 | 1 |
| | 26–50 | 2 |
| | 51–100 | 4 |
| | 101–300 | 5 |
| | 301–500 | 6 |
| | 501–5000 | 6, plus 1 additional for each 150 seats or portion thereof |
| | 5001 and over | 36, plus 1 additional for each 200 seats or portion thereof |
| National Building Code of Canada | 2–100 | 2 |
| | 101–200 | 3 |
| | 201–300 | 4 |
| | 301–400 | 5 |
| | 401–500 | 6 |
| | 501–900 | 7 |
| | 901–1300 | 8 |
| | 1301–1700 | 9 |
| | 1701 and over | 9, plus 1 additional for each 400 seats or portion thereof |

## SIZE AND ARRANGEMENT OF WHEELCHAIR SEATING PLACES

The International Building Code requires wheelchair spaces to be at least 36 in. (914 mm) wide for single-chair spaces and at least 33 in. (838 mm) wide each for multiple adjacent spaces. At least one fixed seat for a companion must be provided beside each required wheelchair space. Wheelchair spaces must be an integral part of the space seating plan. They must be separated into not less than the number of distinct locations indicated in the adjacent table, and these locations must be dispersed to provide a variety of viewing angles and distances, and offer access to multiple seating levels and varying amenities.

The National Building Code of Canada requires wheelchair spaces to be at least 900 mm (35.4 in.) wide, and if entered from the front or rear, at least 1220 mm (48 in.) deep, or if entered from the side, at least 1525 mm (60 in.) deep. Wheelchair spaces should be arranged so that at least two such spaces are located side by side. They should not infringe on any other egress path or width requirements. And they should be distributed so as to provide a choice of viewing location and a clear view of the event taking place.

| Code | Total Capacity | Minimum Number of Separate Wheelchair Locations |
|---|---|---|
| International Building Code | Up to 150 | 1 |
| | 151–500 | 2 |
| | 501–1000 | 3 |
| | 1001–5000 | 3, plus 1 additional for each 1000 seats or portion thereof |
| | 5001 and over | 7, plus 1 additional 2000 seats or portion thereof |

## INTERNATIONAL BUILDING CODE

### Emergency Exterior Door or Window Egress

In I-1 and R Occupancies, basement levels and all sleeping rooms on any level below the fourth story must have an exterior door or window opening for emergency escape and rescue that opens to a public way, or to a yard or court that leads to a public way. These openings must have a sill height of not more than 44 in. (1118 mm), minimum clear opening dimensions of 24 in. (610 mm) high by 20 in. (508 mm) wide, and minimum opening area of at least 5.7 sq ft (0.53 m$^2$).

Emergency escape windows or doors are not required for:

- In other than R-3 Occupancies, buildings that are fully sprinklered
- In other than R-3 Occupancies, sleeping rooms with a door opening to a fire-rated corridor with access to two remote exits in opposite directions
- Sleeping rooms with a door opening directly to a public way, or to a yard, court, or an exit balcony leading to a public way
- Basements with a ceiling height of less than 80 in. (2030 mm), or with no habitable space and less than 200 sq ft (18.6m$^2$) in area
- Buildings over 75 ft (23 m) tall conforming to the code requirements for high-rise buildings

Emergency escape windows and doors may also open onto interior atrium balconies, provided that the balcony leads to an exit and that the dwelling unit has a second independent means of egress that does not pass through the atrium.

### High-Rise Building Egress

*High-rise buildings* are defined as those with occupied floors more than 75 ft (23 m) above the lowest level from which firefighters can deploy ground-based firefighting equipment, excluding open parking garages, airport traffic control towers, outdoor sports arenas, and some low- and medium-hazard industrial tall buildings. Special egress requirements for high-rise buildings include the following:

**Exit Separation:** Entrances to at least two exit stairways must be separated by a straight line measurement of not less than 30 ft (9.1 m) or one-fourth the largest diagonal measurement of the floor area served, whichever is less.

**Number of Exits:** Where the highest roof of a building with other than R-2 Occupancy is more than 420 ft (128 m) above grade, the number of required exits increases by one from the quantities described on page 272 (three exits for fewer than 500 occupants, four exits for fewer than 1000 occupants, etc.). Exit capacity must also be increased and balanced among the exits such that the loss of any single exit does not reduce the remaining exit capacity to less than that required for the occupant load of the area served.

**Smokeproof Exit Enclosures:** Exit stairs must be protected by smokeproof enclosures, as described on page 276.

**Emergency Escape and Rescue Openings:** Emergency escape openings, as described above on this page, are not required (for bedrooms at any level or for basements).

**Fire Service Access Elevator:** In buildings with occupied floors higher than 120 ft (37 m) above grade, at least one elevator designed to provide fire service access must serve every floor in the building. This elevator must travel within an enclosed hoistway and open to enclosed lobbies at each floor. These lobbies must have a minimum area of 150 sq ft (14 m$^2$) and a minimum dimension of 8 ft (2.4 m) and must have direct access to an enclosed exit stair. Fire service lobbies do not need to be enclosed at the ground floor level. Special elevator power, control, and monitoring systems are also required. Fire service access elevators can function as conventional passenger or freight elevators during normal building operation.

**Occupant Evacuation Elevators:** Elevators specially designed for occupant self-evacuation during emergencies are also permitted, though not required. When used, such elevators can take the place of the required additional exit stairway described in Number of Exits above. Requirements for occupant evacuation elevators are similar to those for fire service access elevators. Elevator lobbies must be sized as follows:

- At least 25% of the floor occupant load must be accommodated, at the rate of 3 sq ft (0.28 m$^2$) per person.
- One wheelchair space per 50 occupants (or portion thereof) must be provided.

One elevator can serve for both fire service access and occupant evacuation.

### Underground Building Egress

*Underground buildings* are defined as those with occupied floors more than 30 ft (9 m) below grade, excluding fully sprinklered enclosed garages, stadiums, arenas, and similar facilities, fixed guideway transit systems, fully sprinklered one- and two-family dwellings, and buildings in which only the lowest story is more than 30 ft (9 m) below grade and that story is no more than 1500 sq ft (139 m$^2$) in area, with an occupant load of less than 10. Special egress requirements for underground buildings include the following:

**Number of Exits:** At least two exits are required from every floor.

**Smokeproof Exit Enclosures:** Exit stairs must be protected by smokeproof enclosures, as described on page 276.

**Smoke Compartmentation:** Buildings with floors more than 60 ft (18 m) below grade must have each floor, up to the highest level of exit discharge, divided into at least two compartments with a 1-hour separation between them. Where elevators are provided, each compartment must have direct access to an elevator. Or, where one elevator serves multiple compartments, a lobby with a 1-hour separation from each compartment must be provided.

## NATIONAL BUILDING CODE OF CANADA

### Small Buildings

The National Building Code of Canada includes distinct requirements for *Housing and Small Buildings*, that is, buildings not greater than 600 m$^2$ (6458 sq ft) in horizontal extent, not greater than three stories in height, and serving only C Residential, D Business and Personal Services, E Mercantile, and F-2 or F-3 Medium- or Low-Hazard Industrial Occupancies. Some of the significant differences in requirements for buildings of this type are as follows. See the code for more details.

- Apartment buildings without elevators need only provide barrier-free access to the entrance level of the building. Where the difference in elevation between the entrance level and all dwelling units exceeds 600 mm (24 in.), no barrier-free access need be provided.
- Minimum width for public egress doorways is 800 mm (31 in.).
- Minimum width for public corridors is 900 mm (35 in.).
- Minimum width for public stairways is 900 mm (35 in.) and not less than 8 mm (0.3 in.) per occupant served; for stairways serving single living units, the minimum width is 860 mm (34 in.).
- Limiting stairway tread and riser proportions are reduced. See page 312.
- Emergency egress from bedrooms is required. See below.

### Emergency Bedroom Door or Window Egress

In small buildings, as explained above, dwelling units and other residential suites that are not sprinklered must have a window or door that opens directly to the exterior. Such openings must be operable from the inside without the need of keys, special tools, or special knowledge. Windows must not require the removal of sashes or hardware. The unobstructed opening area must not be less than 0.35 m$^2$ (3.8 sq ft), with a least dimension of 380 mm (15 in.) in either height or width.

### Firefighter Ingress

On unsprinklered floors less than 25 m (82 ft) above grade, firefighter access must be provided by at least one unobstructed window or access panel, with minimum dimensions of 1100 mm (43 in.) high by 550 mm (22 in.) wide with a sill height not greater than 900 mm (35 in.). At least one such opening must be provided for each 15 m (49 ft) of wall facing the street. Access panels above the first floor must allow operation from both the inside and outside or must be glazed with plain glass.

Unsprinklered basements greater than 25 m (82 ft) in any horizontal dimension must provide firefighter access in the form of an exit stair connected directly to the outdoors, or a window or access panel as noted above.

In buildings more than three stories in height with a roof slope less than 1:4, rooftop access must be provided from the floor immediately below, either by a stairway or by a fixed ladder and roof hatch.

### High Buildings

The National Building Code of Canada defines *high buildings* as any of the following:

- Buildings containing A Assembly, D Business and Personal Services, E Mercantile, or F Industrial Occupancies, with a story greater than 36 m (118 ft) above grade
- Buildings containing the same occupancies as above, with a story greater than 18 m (59 ft) above grade where the cumulative occupant load on or above any story above the grade level story, divided by 1.8, exceeds 300 times the width in meters of all exit stairs serving that story
- Buildings with B Care or Detention Occupancies on a story greater than 18 m (59 ft) above grade

- Buildings with B-2 or B-3 Medical Treatment or Care Occupancies on the fourth or higher story
- Buildings with C Residential Occupancies on a story more than 18 m (59 ft) above grade

**Firefighter Access Elevator:** In high buildings, at least one elevator must be provided for firefighter access. This elevator must be located within 15 m (49 ft) of firefighter access to the building, have a usable platform area of not less than 2.2 m$^2$ (24 sq ft), and be protected by an unoccupied ¾-hour vestibule or an unoccupied 1-hour corridor enclosure at each floor. Elevator access must be provided to all floors above grade, by a single elevator, or with not more than one change of elevators.

**Smoke Control:** Special systems are required in high buildings to prevent the spread of smoke between floors, within exit stair enclosures, and between connected buildings.

Stairway enclosures must be provided with smoke control systems such as those described for smokeproof exit stair enclosures on page 276. Additionally, exit stairways must be designed to limit the possibility of smoke from fire on floors below the exit level contaminating stairway enclosures above the exit level. For example, stairway shafts serving floors above and below the exit level must be entirely separated or provided with separations within the shaft.

Elevator shafts serving floors above and below the lowest level of exit discharge must similarly be either entirely separate or, at each floor below the lowest level of exit discharge, a vestibule must separate the elevator from surrounding corridors and spaces.

Connected buildings must be designed to limit the passage of contaminated air between buildings, for example, with fire walls between the buildings and ventilated vestibules to limit the passage of smoke through openings in such walls.

# 2
# SIZING THE EGRESS SYSTEM

***This chapter presents simplified data for use in sizing egress components according to the requirements of the model building codes.***

# HOW TO SIZE THE EGRESS SYSTEM

The various parts of a building's egress system must be sized to accommodate the number of occupants and types of activities within the building so that in the event of an emergency, occupants can safely and efficiently exit the building or move to protected areas. The information you need to complete the design of your building's egress system can be found in the tables and charts beginning on page 299 for the International Building Code and page 305 for the National Building Code of Canada. The following text explains how to apply this information to your project.

## DETERMINING OCCUPANT LOADS

Begin with the Occupant Loads table on either page 299 or page 305, depending on your model code, to determine the number of occupants the various parts of your egress system must serve. For each distinct activity within your building, find the most closely matching use listed in the table and then read the floor area per occupant, or *occupant density*, for that use. Divide the area in your building associated with the activity by the occupant density to determine the number of occupants, or *occupant load*, for that area.

In both model codes, the occupant load for any space is determined by the larger of two calculations: either the number of persons dictated by the tabulated occupant densities, as explained in the previous paragraph, or the actual number of persons for whom the space is intended. For example, consider an open office space 3000 sq ft in area with workstations planned for 35 workers. According to the International Building Code (page 299), the prescribed occupant density for a business use is 100 sq ft per person, and the minimum occupant load for this space is therefore 30. However, since the workstations within the space have been designed to accommodate 35 persons, this second, larger number should be used for determining the capacity of the egress from this area.

Spaces are not always designed for a single purpose. Where a space is intended for more than one activity, the greatest occupant load determined for any of the activities should be used as the basis for sizing the egress system. Where a space designed for one activity could possibly be changed to some other use in the future, one that generates a higher occupant load, it may be appropriate to design the current egress system for such a future use, since enlarging egress system components at a later date is unlikely to be easily accomplished.

Within any floor of a building, occupant loads are cumulative. For example, in a room with a single doorway leading to a corridor, the doorway must be sized to accommodate the number of occupants in that room. However, where one room discharges into a second room that then opens to a corridor, the door opening to the corridor must be sized to accommodate the combined occupant load of both rooms. Likewise, corridors must be sized to accommodate the number of occupants from all spaces that discharge through them. And doorways into exit stairways and the stairways themselves must each be sized to accommodate their apportioned share of all the occupants of a floor.

Occupant loads from multiple floors are normally not cumulative. Thus, within an exit stairway, the width of the stairway and its discharge to the exterior are sized for the number of occupants from the single largest floor served, but not for the total number of occupants on all floors served by the stair. However, where egress paths from floors above and below converge at an intermediate level within a stairway or passageway, the egress width from that point on must be based on the sum of the converging occupant loads. Mezzanine occupants are also normally treated in this manner. That is, where a mezzanine discharges through the floor below, egress components serving that floor are sized for the combined occupant load of the floor and the mezzanine.

The National Building Code of Canada also requires converging occupant loads from interconnected floor spaces or from multiple theater balconies to be treated cumulatively unless alternative protected areas for temporary occupant holding area provided. See the code for details.

## EGRESS SYSTEM CRITERIA ACCORDING TO OCCUPANCY GROUP

The next step in sizing the egress system is to refer to the Occupancy Criteria table on either page 300 or page 306. For each building Occupancy classification, information such as maximum travel distance, minimum width of corridors and stairs, permitted length of dead-end corridors, and other requirements can be found. (If you have not already done so, turn to pages 6–17 to determine the Occupancy Groups for your building.) If your building is single-occupancy, the requirements for that Occupancy apply throughout. If your building is mixed occupancy, the requirements for each Occupancy should be applied to the portion of the building serving that Occupancy. Where criteria in this table vary with the number of occupants served, use the occupant loads you calculated in the previous step to determine the appropriate requirements.

## EGRESS COMPONENT CAPACITY

As the final step, calculations are performed to check the width of each door, corridor, ramp, stairway, and other components of the egress system to ensure that each has sufficient capacity for the number of occupants served. Required widths based on occupant load are determined using the Egress Component Capacity table (page 302 or page 308). For example, in the International Building Code, the minimum clear width for a doorway providing egress for 188 occupants in a sprinklered business use area would be calculated as follows:

> 188 persons × 0.20 in. per
> person = 37.6 in., rounded up
> to 38 in.

Taking into account the geometry of an opened door and its frame, not less than a nominal 40-in. wide doorway should be provided. Similar calculations should be performed for each component in the egress system. As a shortcut to performing these calculations, the Egress Width Calculator charts, on page 303 or page 309, can be used to determine these numbers graphically.

Note that egress components must meet the requirements of both tables, Occupancy Criteria and Egress Component Capacity. For example, consider a doorway serving a business use area, this time serving an occupant load of 150. According to the Egress Component Capacity table, a minimum width of 30 in. is required (150 × 0.20 in. = 30 in.). However, since the Occupancy Criteria table lists a minimum doorway width of 32 in., this larger figure must be used. Further examples of calculating required widths of egress components using either model code are included on pages 302 and 308.

In determining the widths of egress components, the following should also be considered: Means of egress capacity may not diminish in the direction of egress travel. For example, an exit stairway providing egress for 50 occupants may not lead to an exit passageway with a capacity of only 40 occupants. Likewise, a stairway providing an egress capacity of 50 persons exiting from the fourth floor of a building must maintain at least that capacity all the way to the ground-level exit discharge, even if lower floors require a capacity of only 40 persons each.

Where a space or floor requires more than one independent means of egress, the required egress capacity is distributed among the various egress ways provided. In such cases, the capacity of the egress ways should be balanced such that the loss of any single one will not render the remaining capacity less than half of the total required. For example, consider an assembly hall with an occupant load of 600 persons and three means of egress, where the main entrance provides a capacity of 400 persons and the two remaining exits provide a capacity of 100 persons each. Even though a total egress capacity of 600 has been provided, elimination of the main entrance would leave a remaining capacity of only 200 persons. Since 200 is less than half of 600, this arrangement is not permitted. One solution to this problem would be to increase the size of just one of the smaller exits to a capacity of 200 persons. In this way, the elimination of any single exit still preserves an egress capacity of 300 or more.

In the table on the facing page, *gross area* includes all floor area inside of exterior walls, excluding only interior vent shafts and courts. *Net area* is intended to include only the actual occupied floor area and should exclude, for example, shafts, fixed equipment, corridors, stairways, toilet rooms, service rooms, closets, and the plan area occupied by all walls and partitions.

# INTERNATIONAL BUILDING CODE

## OCCUPANT LOADS

| Use | Floor Area per Occupant |
|---|---|
| Accessory storage area | 300 ft$^2$ (28 m$^2$) gross |
| Agricultural buildings | 300 ft$^2$ (28 m$^2$) gross |
| Aircraft hangers | 500 ft$^2$ (46 m$^2$) gross |
| Airport terminal baggage claim | 20 ft$^2$ (1.86 m$^2$) gross |
| Airport terminal baggage handling | 300 ft$^2$ (28 m$^2$) gross |
| Airport terminal concourses | 100 ft$^2$ (9.3 m$^2$) gross |
| Airport terminal waiting areas | 15 ft$^2$ (1.4 m$^2$) gross |
| Assembly Occupancy, gaming floors | 11 ft$^2$ (1.0 m$^2$) gross |
| Assembly Occupancy, concentrated seating (chairs only, not fixed) | 7 ft$^2$ (0.65 m$^2$) net |
| Assembly Occupancy, standing space | 5 ft$^2$ (0.46 m$^2$) net |
| Assembly Occupancy, unconcentrated seating (tables, chairs, stages, platforms) | 15 ft$^2$ (1.4 m$^2$) net<br>For booth seating without dividing arms, use an 18" (457-mm) width per occupant. |
| Bowling centers | 5 occupants per lane plus 7 ft$^2$ (0.65 m$^2$) net for other areas |
| Business areas | 100 ft$^2$ (9.3 m$^2$) gross |
| Courtrooms, other than fixed seating | 40 ft$^2$ (3.7 m$^2$) net |
| Day care areas | 35 ft$^2$ (3.3 m$^2$) net |
| Educational Occupancy, classroom areas | 20 ft$^2$ (1.86 m$^2$) net |
| Educational Occupancy, shops and vocational areas | 50 ft$^2$ (4.65 m$^2$) net |
| Exercise areas | 50 ft$^2$ (4.65 m$^2$) gross |
| Factories, industrial areas | 100 ft$^2$ (9.3 m$^2$) gross |
| Hazardous Occupancies: Groups H-1, H-2, H-3, H-4 | 100 ft$^2$ (9.3 m$^2$) gross |
| Hazardous Occupancies: Groups H-5 | 200 ft$^2$ (18.6 m$^2$) gross |
| Institutional Occupancy, sleeping areas | 120 ft$^2$ (11.2 m$^2$) gross |
| Institutional Occupancy, inpatient treatment areas | 240 ft$^2$ (22.3 m$^2$) gross |
| Institutional Occupancy, outpatient treatment areas | 100 ft$^2$ (9.3 m$^2$) gross |
| Kitchens, commercial | 200 ft$^2$ (18.6 m$^2$) gross |
| Libraries, reading rooms | 50 ft$^2$ (4.65 m$^2$) net |
| Libraries, stack areas | 100 ft$^2$ (9.3 m$^2$) gross |
| Locker rooms | 50 ft$^2$ (4.65 m$^2$) gross |
| Mechanical equipment rooms | 300 ft$^2$ (28 m$^2$) gross |
| Mercantile Occupancy, areas other than listed below | 60 ft$^2$ (5.6 m$^2$) gross |
| Mercantile Occupancy, basement and grade floor levels | 30 ft$^2$ (2.8 m$^2$) gross |
| Mercantile Occupancy, enclosed shopping malls | Between 30 and 50 ft$^2$ (2.8 and 4.65 m$^2$) gross leasable area; consult the code |
| Mercantile Occupancy, storage, stock, and shipping areas | 300 ft$^2$ (28 m$^2$) gross |
| Parking garages | 200 ft$^2$ (19 m$^2$) gross |
| Residential Occupancy, dormitories | 50 ft$^2$ (4.65 m$^2$) gross |
| Residential Occupancy, general | 200 ft$^2$ (19 m$^2$) gross |
| Skating rinks and swimming pools, rink and pool area | 50 ft$^2$ (4.65 m$^2$) gross |
| Skating rinks and swimming pools, decks | 15 ft$^2$ (1.4 m$^2$) gross |
| Stages and Platforms | 15 ft$^2$ (1.4 m$^2$) gross |
| Storage | 300 ft$^2$ (28 m$^2$) gross |
| Warehouses | 500 ft$^2$ (46 m$^2$) gross |

# INTERNATIONAL BUILDING CODE

## OCCUPANCY CRITERIA

| Occupancy (pp. 6–17) | Maximum Travel Distance (p. 267) | | Maximum Common Path of Egress Travel (p. 268) | Largest Area with Single Exit (p. 272) |
|---|---|---|---|---|
| | **Unsprinklered** | **Sprinklered** | | |
| A: Assembly | 200' (61 m)<br>400' (122 m) for open-air seating with combustible construction or unlimited distance with noncombustible construction | 250' (76 m) | 30' (9 m) for assembly fixed seating with 50 or more occupants<br>75' (23 m) for others | 49 occupants |
| B: Business | 200' (61 m) | 300' (91 m) | 75' (23 m) unsprinklered<br>100' (30 m) sprinklered or for unsprinklered areas with an occupant load of 30 or less | 49 occupants |
| E: Educational | 200' (61 m) | 250' (76 m) | 75' (23 m) | 49 occupants |
| F-1: Factory, Moderate Hazard | 200' (61 m) | 250' (76 m) | 75' (23 m) unsprinklered<br>100' (30 m) sprinklered | 49 occupants |
| F-2: Factory, Low Hazard | 300' (91 m) | 400' (122 m) | Same as above | 49 occupants |
| H-1, H-2, H-3: Hazardous | Not permitted | H-1: 75' (23 m)<br>H-2: 100' (30 m)<br>H-3: 150' (46 m) | 25' (8 m) | 3 occupants |
| H-4, H-5: Hazardous | Not permitted | H-4: 175' (53 m)<br>H-5: 200' (61 m) | 75' (23 m) | 10 occupants |
| I-1: Institutional, Residential Care | Not permitted | 250' (76 m) | 75' (23 m) | 10 occupants |
| I-2: Institutional, Custodial Care | Not permitted | 200' (61 m) | 75' (23 m)<br>100' (30 m) for sleeping room suites | 1000 $ft^2$ (93 $m^2$) for sleeping rooms or suites; 2500 $ft^2$ (232 $m^2$) for other areas |
| I-3 Institutional, Detention and Security | Not permitted | 200' (61 m) | 100' (30 m) | 10 occupants |
| I-4: Institutional, Day Care | Not permitted | 200' (61 m) | 75' (23 m) | 10 occupants |
| M: Mercantile | 200' (61 m) | 250' (76 m) | 75' (23 m) | 49 occupants |
| M: Mercantile, Covered malls | Not permitted | 200' (61 m) from within tenant space to common circulation<br>200' (61 m) from within common circulation to an exit | 75' (23 m) | 49 occupants |
| R-1: Hotels and Motels | Not permitted | 250' (76 m)<br>200' (61 m) with NFPA 13R sprinkler system | 75' (23 m) | 10 occupants |
| R-2: Residential, Multifamily | Not permitted | Same as above | 125' (38 m)<br>75' (23 m) with NFPA 13R sprinkler system | 10 occupants |
| R-3: Residential, One- and Two-Family, except below | Not permitted | 250' (76 m)<br>200' (61 m) with NFPA 13D sprinkler system | 75' (23 m) | 10 occupants |
| Detached, three-story maximum, one- and two-family dwellings and townhouses | Not applicable | Not applicable | Not applicable | Not applicable |
| R-4: Residential, Assisted Living | Not permitted | 250' (76 m) | 75' (23 m) | 10 occupants |
| S-1: Storage, Moderate Hazard | 200' (61 m) | 250' (76 m) | 75' (23 m) unsprinklered<br>100' (30 m) sprinklered or for unsprinklered areas with an occupant load of 30 or less | 29 occupants |
| S-2: Storage, Low Hazard, and Parking Garages | 300' (91 m) | 400' (122 m) | Same as above | 29 occupants |
| U: Utility, and Private Garages | 300' (91 m) | 400' (122 m) | 75' (23 m)<br>100' (30 m) for areas with an occupant load of 30 or less | 49 occupants |

| Minimum Length of Dead-End Corridor (p.270) | For minimum widths based on occupant load, see pages 298–299. For minimum dimensions of accessible routes, see pages 281–282. | | | Other Requirements |
|---|---|---|---|---|
| | Minimum Door Width (p. 271) | Minimum Corridor Width | Minimum Stair Width | |
| Greater of 20' (6 m) or 2.5 × width of corridor | Min: 32" (813 mm) net clear<br>Max: 48" (1220 mm) nominal | 44" (1118 mm) serving more than 49 occupants<br>36" (914 mm) serving 49 or fewer | 44" (1118 mm) serving more than 49 occupants<br>36" (914 mm) serving 49 or fewer | For special egress requirements in assembly seating areas, see pages 287–289. |
| Greater of 20' (6 m) unsprinklered, 50' (15 m) sprinklered, or 2.5 × width of corridor | Same as above | Same as above | Same as above | |
| Same as above | Same as above | Same as above, except 72" (1829 mm) for 100 or more occupants | Same as above | |
| Same as above | Same as above | 44" (1118 mm) serving more than 49 occupants<br>36" (914 mm) serving 49 or fewer | Same as above | |
| Same as above | Same as above | Same as above | Same as above | |
| Greater of 20' (6 m) or 2.5 × width of corridor | Same as above | Same as above | Same as above | Consult the code for special requirements. |
| Same as above | Same as above | Same as above | Same as above | Consult the code for special requirements. |
| Greater of 20' (6 m) sprinklered (NFPA 13R), 50' (15 m) sprinklered (NFPA 13), or 2.5 × width of corridor | Same as above | Same as above, except 72" (1829 mm) where occupants are incapacitated | Same as above | For required emergency egress from sleeping areas, see page 291. |
| Greater of 20' (6 m) or 2.5 × width of corridor | Min: 32" (813 mm) net clear; 41.5" (1054 mm) where beds must be moved<br>Max: 48" (1220 mm) nominal | Same as I-1 above, except 96" (2438 mm) where beds must be moved | Same as above | Each floor must be subdivided by at least one smokeproof wall with horizontal exits. |
| Greater of 20' (6 m) or 2.5 × width of corridor<br>50' (15 m) under some conditions; consult the code | Min: 32" (813 mm) net clear; 28" (711 mm) for resident sleeping rooms<br>Max: 48" (1220 mm) nominal | 44" (1118 mm) serving more than 49 occupants<br>36" (914 mm) serving 49 or fewer | Same as above | Same as above<br>Doors opening to sleeping units 44 in. (1118 m) or wider are exempt from normal accessible latch side clearance requirements |
| Greater of 20' (6 m) or 2.5 × width of corridor | Min: 32" (813mm) net clear<br>Max: 48" (1220 mm) nominal | Same as above | Same as above | |
| Greater of 20' (6 m) unsprinklered, 50' (15 m) sprinklered, or 2.5 × width of corridor | Same as above | Same as above | Same as above | |
| Greater of 20' (6 m) or 2 × mall width | Same as above | 20' (6 m) for mall space<br>66" (1676 mm) for corridors | Same as above | Consult the code for special egress requirements. |
| Greater of 20' (6 m) sprinklered (NFPA 13R), 50' (15 m) sprinklered (NFPA 13), or 2.5 × width of corridor | Same as above | 44" (1118 mm) serving more than 49 occupants<br>36" (914 mm) serving 49 or fewer, or within dwelling units | Same as above | For required emergency egress from sleeping areas, see page 291. |
| Same as above | Same as above | Same as above | Same as above | Same as above |
| Greater of 20' (6 m) or 2.5 × width of corridor | Same as above | Same as above | Same as above | Same as above |
| Not applicable | Same as above | 36" (914 mm) | 36" (914 mm) | Same as above |
| Greater of 20' (6 m) sprinklered (NFPA 13R) 50'(15 m) sprinklered (NFPA 13), or 2.5 × width of corridor | Min: 32" (813 mm) net clear<br>Max: 48" (1220 mm) nominal | 44" (1118 mm) serving more than 49 occupants<br>36" (914 mm) serving 49 or fewer, or within dwelling units | 44" (1118 mm) serving more than 49 occupants<br>36" (914 mm) serving 49 or fewer | Same as above |
| Same as above | Same as above | 44" (1118 mm) serving more than 49 occupants<br>36" (914 mm) serving 49 or fewer | Same as above | |
| Same as above | Same as above | Same as above | Same as above | Open parking garage exit stairways may be unenclosed |
| Same as above | Same as above | Same as above | Same as above | |

## DETERMINING WIDTHS OF EGRESS COMPONENTS

Use the following chart to determine the minimum required width for the various parts of an egress system based on the occupant load served.

### An Example Egress System Sizing Exercise

**The Problem:** Design the egress system for a department store basement, sprinklered, dimensions 105 × 292 ft.

**The Solution:** From the index on page 10, we find that a department store is classified as an M Mercantile Occupancy. Multiplying the dimensions of the floor, we arrive at a gross area of 30,660 sq ft. From the Occupant Loads table on page 299, we see that for purposes of egress design, we must allocate at least 30 sq ft per occupant to arrive at an occupant load of 1022 persons for this floor. According to the information on page 272, a minimum of four exits is required. Assuming the occupant load is divided equally among the four, each exit must serve 256 persons.

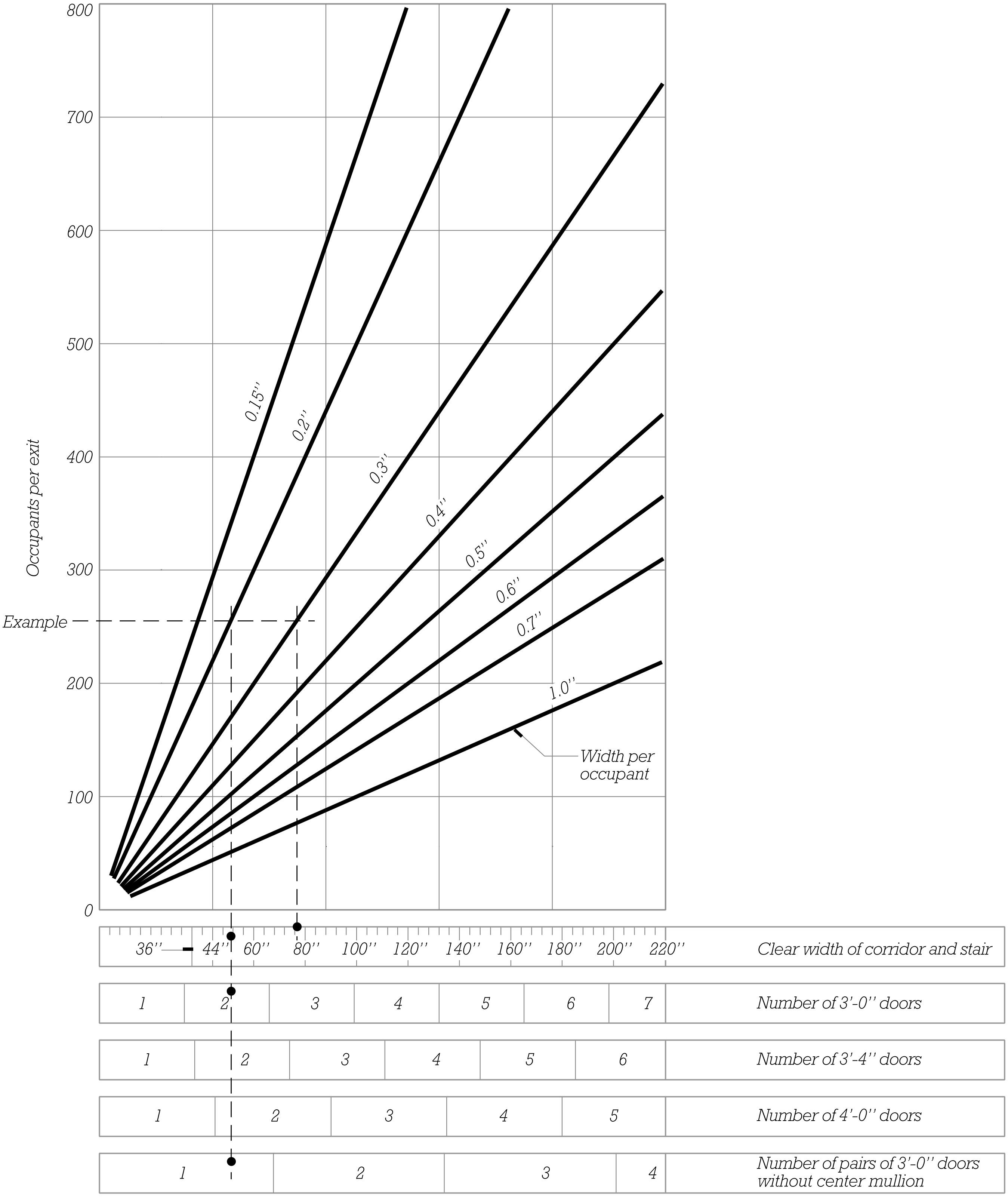
From the Egress Component Capacity table on this page, we find that we must provide 0.20 in. of width per occupant in corridors and doorways and 0.3 in. per occupant in stairways. Moving to the chart on the facing page, we read horizontally from 256 occupants to the 0.20-in. line and then down to find that a width of 52 in. is required for the corridor. We compare this with the 44-in. minimum width indicated on page 301 and choose the larger of the two, 52 in. in this example. Extending this line farther downward, we select either two 3-ft doors or a pair of 3-ft doors without center mullion.

Reading horizontally from 256 occupants to the 0.3-in. line, then downward, we arrive at a required stair width of 77 in. (For stair design charts, see pages 315–325.)

**EGRESS COMPONENT CAPACITY**

| | Width per Occupant | |
|---|---|---|
| **Occupancy** | **Doorways, Corridors, Ramps, and Other Components** | **Stairs** |
| All occupancies | 0.2" (5 mm) per person | 0.3" (8 mm) |

## EGRESS WIDTH CALCULATOR



# NATIONAL BUILDING CODE OF CANADA

## SIZING THE EGRESS SYSTEM

Instructions for using the charts on this and the following pages begin on page 297.

### OCCUPANT LOADS

| Occupancy | Use | Floor Area per Occupant |
|---|---|---|
| A: Assembly | Space with fixed seats | Actual number of seats |
| | Space with nonfixed seats, performance stages | 0.75 m$^2$ (8.1 ft$^2$) |
| | Space with nonfixed seats and tables | 0.95 m$^2$ (10 ft$^2$) |
| | Standing space | 0.40 m$^2$ (4.3 ft$^2$) |
| | Bowling alleys, pool and billiard rooms, school shops and vocational rooms | 9.30 m$^2$ (100 ft$^2$) |
| | Classrooms, reading or writing rooms, lounges | 1.85 m$^2$ (20 ft$^2$) |
| | Dining, beverage, and cafeteria spaces | 1.20 m$^2$ (13 ft$^2$) |
| | Laboratories in schools | 4.60 m$^2$ (50 ft$^2$) |
| | Stadiums and grandstands | 0.60 m$^2$ (6.5 ft$^2$) |
| B: Care, Treatment, and Detention | Suites | 2 persons per sleeping room in suite |
| | Care, treatment, and sleeping areas | 10.00 m$^2$ (107 ft$^2$) |
| | Detention quarters | 11.60 m$^2$ (125 ft$^2$) |
| C: Residential | Dwelling units | 2 persons per sleeping room |
| | Dormitories | 4.60 m$^2$ (50 ft$^2$) |
| D: Business and Personal Services | Personal services shops | 4.60 m$^2$ (50 ft$^2$) |
| | Offices | 9.30 m$^2$ (100 ft$^2$) |
| E: Mercantile | Basements, first stories, second stories having a principal entrance from a pedestrian thoroughfare or a parking area | 3.70 m$^2$ (40 ft$^2$) |
| | Other stories | 5.60 m$^2$ (60 ft$^2$) |
| F: Industrial | Manufacturing or processing rooms | 4.60 m$^2$ (50 ft$^2$) |
| | Storage garages (parking), aircraft hangers | 46.00 m$^2$ (495 ft$^2$) |
| | Storage spaces (warehouses) | 28.00 m$^2$ (300 ft$^2$) |
| Other | Cleaning and repair goods | 4.60 m$^2$ (50 ft$^2$) |
| | Kitchens | 9.30 m$^2$ (100 ft$^2$) |
| | Public corridors intended for occupancy in addition to circulation | 3.70 m$^2$ (40 ft$^2$) |

## EGRESS SYSTEM CRITERIA

| | Maximum Travel Distance (See also page 267) | | Limits on Room or Suite That May Have Only One Exit Access | |
|---|---|---|---|---|
| **Occupancy** | **Unsprinklered** | **Sprinklered** | **Unsprinklered** | **Sprinklered** |
| A-1: Assembly, Theaters | Not permitted | 45 m (148 ft) | Not permitted | Occupancy: 60<br>Travel distance in room: 25 m (82 ft)<br>Area: 200 m$^2$ (2153 ft$^2$) |
| A-2: Assembly, Miscellaneous | 30 m (98 ft) | 45 m (148 ft) | Occupancy: 60<br>Travel distance in room: 15 m (49 ft)<br>Area: 150 m$^2$ (1615 ft$^2$) | Same as above |
| A-3: Assembly, Arenas | 30 m (98 ft) | 45 m (148 ft) | Same as above | Same as above |
| A-4: Assembly, Open Air | 45 m (148 ft) to the ground, an exit, an opening leading from the seating area, or an opening through the seating deck structure | Not applicable | Same as above | Same as above |
| B-1: Detention | Not permitted | 45 m (148 ft) | Not permitted | Same as above, except area: 100 m$^2$ (1076 ft$^2$) |
| B-2: Medical Treatment | Not permitted | 45 m (148 ft) | Not permitted | Same as above, except area: 100 m$^2$ (1076 ft$^2$) sleeping rooms, 200 m$^2$ (2153 ft$^2$) other areas |
| B-3: Care | Not permitted | 45 m (148 ft) | Not permitted | Same as above, except area: 100 m$^2$ (1076 ft$^2$) sleeping rooms, 150 m$^2$ (1615 ft$^2$) sleeping suites, 200 m$^2$ (2153 ft$^2$) other areas |
| C: Residential | 30 m (98 ft) | 45 m (148 ft) | Occupancy: 60<br>Travel distance in room: 15 m (49 ft)<br>Area: 100 m$^2$ (1076 ft$^2$) | Same as above, except area: 150 m$^2$ (1615 ft$^2$) |
| D: Business and Personal Services | 40 m (131 ft) | 45 m (148 ft) | Occupancy: 60<br>Travel distance in room: 25 m (82 ft)<br>Area: 200 m$^2$ (2153 ft$^2$) | Same as above, except area: 300 m$^2$ (3229 ft$^2$) area |
| E: Mercantile | 30 m (98 ft) | 45 m (148 ft) | Occupancy: 60<br>Travel distance in room: 15 m (49 ft)<br>Area: 150 m$^2$ (1615 ft$^2$) | Same as above, except area: 200 m$^2$ (2153 ft$^2$) |
| F-1: Industrial, High-Hazard | 25 m (82 ft) | 25 m (82 ft) | Occupancy: 60<br>Area: 15 m$^2$ (161 ft$^2$) | Occupancy: 60<br>Area: 15 m$^2$ (161 ft$^2$) |
| F-2: Industrial, Medium-Hazard | 30 m (98 ft) | 45 m (148 ft) | Occupancy: 60<br>Travel distance in room: 10 m (33 ft)<br>Area: 150 m$^2$ (1615 ft$^2$) | Occupancy: 60<br>Travel distance in room: 25 m (82 ft)<br>Area: 200 m$^2$ (2153 ft$^2$) |
| F-3: Industrial, Low-Hazard | 30 m (98 ft) | 45 m (148 ft) | Occupancy: 60<br>Travel distance in room: 15 m (49 ft)<br>Area: 200 m$^2$ (2153 ft$^2$) | Same as above, except area: 300 m$^2$ (3229 ft$^2$) |
| F-3: Open-Air Garages | 60 m (197 ft) | 60 m (197 ft) | Not applicable | Not applicable |

# NATIONAL BUILDING CODE OF CANADA

| | See also minimum width requirements for occupant load served on pages 298 and 305 and for accessible routes on pages 285–286. | | | |
|---|---|---|---|---|
| **Maximum Length of Dead-End Corridor (page 270)** | **Minimum Clear Corridor Width** | **Minimum Net Clear Egress Door Width** | **Minimum Stair Width** | **Additional Requirements** |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | See requirements for row spacing, aisles, and exits on pages 287–289. |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | Same as above |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | Same as above |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | Maximum 25 m (82 ft) between exits. See the code for aisle and bleacher requirements. |
| None, except when the area served by the corridor has a separate independent means of egress | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | |
| Same as above | 1650 mm (65 in.)<br>2400 mm (94 in.) serving patients in beds<br>1100 mm (43 in.) for exit passageways | 800 mm (31 in.) within suites<br>850 mm (33 in.) within public corridors and exits<br>1050 mm (41 in.) serving patients in beds | 900 mm (35 in.)[a]<br>1100 mm (43 in.) 1650 mm (65 in.) serving residents from sleeping rooms | See page 278 for refuge area requirements. |
| Same as above, or 6 m (20 ft) when serving a residential suite | 1100 mm (43 in.) serving not more than 10 residents<br>1650 mm (65 in.)<br>1100 mm (43 in.) for exit passageways | 800 mm (31 in.) within suites<br>850 mm (33 in.) within public corridors and exits | 900 mm (35 in.)[a]<br>1100 mm (43 in.)<br>Serving 10 or more residents from sleeping rooms:<br>1100 mm (43 in.) [a]<br>1650 mm (65 in.) | Same as above |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | |
| 6 m (20 ft) | 1100 mm (43 in.) | 800 mm (31 in.) | 900 mm (35 in.)[a]<br>1100 mm (43 in.) | |

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[a] Serving not more than two stories above or one story below the lowest exit level.

## DETERMINING WIDTHS OF EGRESS COMPONENTS

Use the following chart to determine the minimum required width for the various parts of an egress system based on the occupant load served.

### An Example Egress Sizing Exercise

**The Problem:** Design an exit for a department store basement, dimensions 33 × 85.2 m.

**The Solution:** From the index on page 15, we find that a department store is classified as an E Mercantile Occupancy. Multiplying the two dimensions of the floor, we arrive at a gross area of 2812 $m^2$. From the Occupant Loads table on page 305, we see that for purposes of egress design, we must allocate 3.7 $m^2$ per occupant to arrive at an occupant load of 760 persons for this floor. Assume that our design provides four exits. Dividing 760 occupants by four exits gives an occupant load per exit of 190.

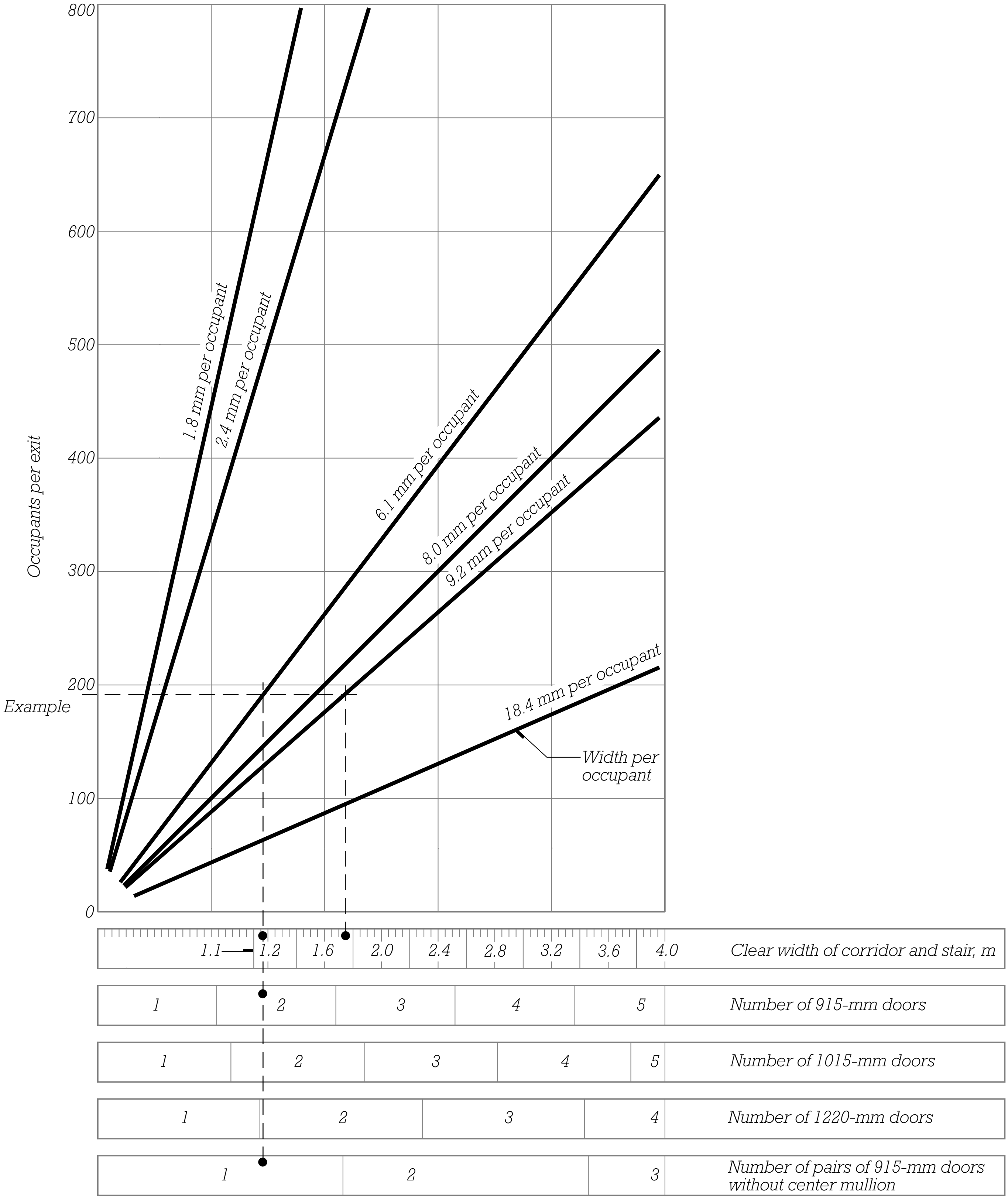
From the Egress Component Capacity table on this page, we find that for an E Occupancy, 6.1 mm of width per occupant is required for doors, corridors, and passageways. Moving to the chart on the facing page, we read horizontally from 190 occupants to the 6.1-mm line, then downward, to find that a corridor width of 1160 mm is required. Extending this line farther downward, we select either two 915-mm doors or one pair of 915-mm doors without a center mullion.

To find the required width for our egress stair, we read downward from the 9.2-mm line, finding that a width of 1750 mm is required for the steepest possible stair. (For stair design tables, see pages 315–325.)

**EGRESS COMPONENT CAPACITY**

| | Width per Occupant | | |
|---|---|---|---|
| **Occupancy** | **Doors, Corridors, Ramps with Not More Than 1:8 Slope** | **Stairs with Rise Not More Than 180 mm (7") and Run Not Less Than 280 mm (11")** | **Other Ramps and Stairs** |
| A-4: Open Air Assembly | 2.4 mm (0.09") for exit stairs<br>1.8 mm (0.07") for aisles, ramps, passageways, exits, and stairs other than exit stairs | | |
| B-2: Medical Treatment<br>B-3: Care | 18.4 mm (0.72") | 18.4 mm (0.72") | 18.4 mm (0.72") |
| All other occupancies | 6.1 mm (0.24") | 8 mm (0.31") | 9.2 mm (0.36") |

**EGRESS WIDTH CALCULATOR**



# 3

# STAIRWAY AND RAMP DESIGN

***This chapter will help you design stairways and ramps in accordance with the model building codes.***

## STAIRS

In the following table, International Building Code *Residential Stairs* includes stairs in R-3 Occupancies, within dwelling units in R-2 Occupancies, and in U Occupancies accessory to R-3 Occupancies.

National Building Code of Canada *Residential Stairs* includes stairs within dwelling units and exterior stairs serving individual dwelling units. This code also requires interior egress stairs to have at least three risers, except within dwelling units or A-2 Occupancies used for serving food and beverages when the stair is not less than 900 mm (35 in.) wide.

| | **Nonresidential Stairs** | | | **Residential Stairs** | | |
|---|---|---|---|---|---|---|
| **Code** | **Maximum Riser Height** | **Minimum Riser Height** | **Minimum Tread Run** | **Maximum Riser Height** | **Minimum Tread Run** | **Maximum Vertical Distance Between Landings** |
| International Building Code | 7" (178 mm) | 4" (102 mm) | 11" (279 mm) | 7.75" (197 mm) | 10" (254 mm) | 12' (3658 mm) |
| National Building Code of Canada | 180 mm (7.1") | 125 mm (4.9") | 280 mm (11.0") | 200 mm (7.9") | 235 mm (9.3") | 3.7 m (12'-2")<br>2.4 m (7'-10") in a B-2 Occupancy |

## RAMPS

In the International Building Code, landings are required for ramps at points of turning, at ramp entrances and exits, and at doors opening onto ramps. Landings must be at least as wide as the ramp. Landings on accessible routes must be at least 60 in. (1525 mm) long. When not part of an accessible route, landings may be 48 in. (1220 mm) long, or if within non-accessible R-2 or R-3 individual dwelling units, not less than 36 in. (9144 mm) long.

In the National Building Code of Canada, where a doorway or stairway opens onto the side of a ramp, a landing extending a minimum of 300 mm (11.8 in.) beyond either side of the opening is required. Where a doorway or stairway opens onto the end of a ramp, a landing extending along the ramp for at least 900 mm (35.4 in.) is required. In addition, barrier-free ramps require landings with a minimum size of 1500 mm (59 in.) square at the top and bottom of the ramp, and landings at least 1200 mm (47.25 in.) long and at least as wide as the ramp at abrupt changes in direction of the ramp.

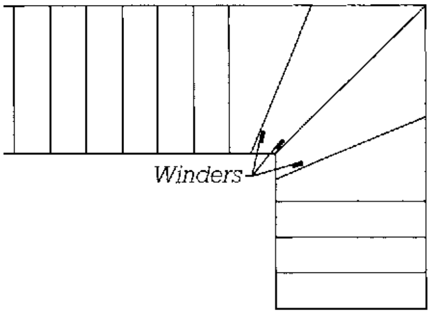
### RAMP PROPORTIONS

| | **Maximum Ramp Slope** | **Minimum Width** | **Maximum Distance Between Landings** |
|---|---|---|---|
| International Building Code | 1:12 for ramps part of a means of egress or on accessible routes<br>1:8 other ramps | 36" (914 mm) clear between sides of ramp, or handrails, if any | 30" (762 mm) rise |
| National Building Code of Canada | 1:12 barrier-free ramps<br>1:10 A, B, or C Occupancies<br>1:6 E or F Occupancies<br>1:8 other interior ramps<br>1:10 other exterior ramps | 870 mm (34.25") between handrails of barrier-free ramps<br>1100-mm (43") exit ramps<br>1650-mm (65") exit ramps serving B-2 Occupancy sleeping rooms<br>870-mm (34") exit ramps serving Small Building (p. 292) Occupancies<br>860 mm (34") serving dwelling units | 9-m (29'-6") run barrier-free ramps<br>1500-mm (59") rise for other ramps |

# WINDING, CURVED, AND SPIRAL STAIRS

## MAY WINDERS WITHIN STRAIGHT STAIRS SERVE AS PART OF A REQUIRED MEANS OF EGRESS?

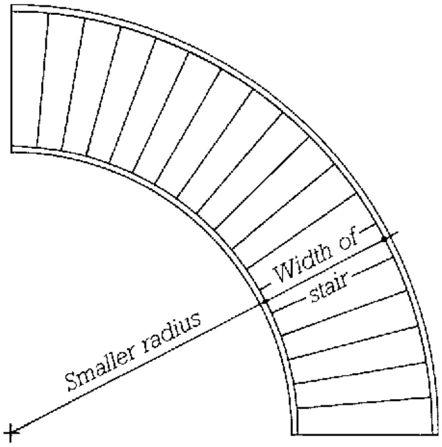
| | | Dimensional Restrictions |
|---|---|---|
| International Building Code | Only within individual dwelling units | See tread and riser limits for residential stairs on page 312. Tread depth is measured 12" (305 mm) from the narrow end.<br>Minimum depth at the narrow end is 10" (254 mm) for nonresidential stairs and 6" (152 mm) for residential stairs. |
| National Building Code of Canada | Only within individual dwelling units | One set of winders per floor level, arrayed at either 30° or 45°, up to 90° total.<br>Winders may converge to a point. |



WINDERS IN A STRAIGHT STAIR

## MAY CURVED OR CIRCULAR STAIRS SERVE AS PART OF A REQUIRED MEANS OF EGRESS?

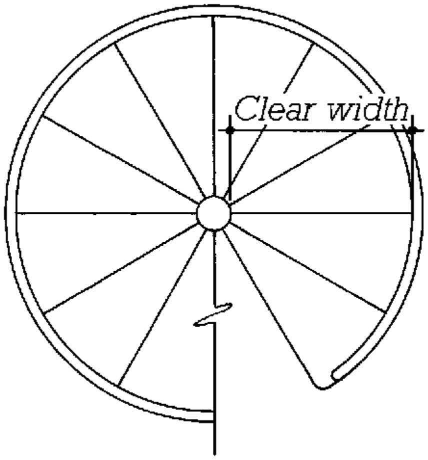
| | | Dimensional Restrictions |
|---|---|---|
| International Building Code | Yes | See tread and riser limits for nonresidential and residential stairs on page 312. Tread depth is measured 12" (305 mm) from the narrow end.<br>Minimum depth at the narrow end is 10" (254 mm) for nonresidential stairs and 6" (152 mm) for residential stairs.<br>For nonresidential stairs, the smaller radius of the stair must be at least twice the required width of the stairway. |
| National Building Code of Canada | Yes | For tread and riser dimensions, see the Stair Proportions table on page 312, with tread depth measured 230 mm (9.1") from the narrow end of the tread.<br>Minimum tread depth is 240 mm (9.4") at the narrow end.<br>The smaller radius of the stair must be at least twice the width of the stairway.<br>For restrictions when not part of a means of egress, see Spiral Stairs, page 314. |



CURVED STAIR

## MAY SPIRAL STAIRS SERVE AS PART OF A REQUIRED MEANS OF EGRESS?

| | | Dimensional Restrictions |
|---|---|---|
| International Building Code | Yes, within individual dwelling units, or from a space not more than 250 ft$^2$ (23 m$^2$) in area serving not more than 5 occupants | Minimum tread depth 7½" (191 mm) measured 12" (305 mm) from the narrow side<br>Maximum riser height 9½" (241 mm)<br>Minimum clear width 26" (660 mm)<br>Minimum head room 78" (1981 mm) |
| National Building Code of Canada | No | When not part of the means of egress:<br>Minimum tread depth 150 mm (7.9") at any point, 200 mm (7.9") average<br>Maximum riser height 180 mm (7.1")<br>Minimum riser height 125 mm (4.9") |



SPIRAL STAIR

# EXIT STAIRWAY DESIGN TABLES

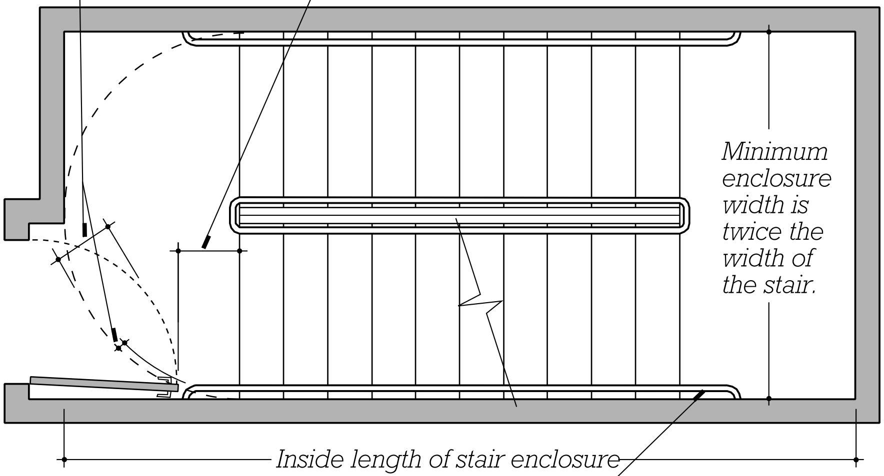
The tables that follow allow you to complete a rapid preliminary design for an exit stairway. After selecting the desired stairway configuration, consult an accompanying table to find the required interior dimensions and the tread and riser proportions of a stairway that correspond to the stair width and floor-to-floor height for which you are designing.

The stairway lengths for the English-unit tables are based on a maximum 7-in. (178-mm) riser and minimum 11-in. (279-mm) tread, conforming to the requirements of the International Building Code. Stairway lengths for the metric tables are based on a maximum 180-mm (7.1-in.) riser and minimum 280-mm (11-in.) tread, conforming to the requirements of the National Building Code of Canada for buildings not classified as small or residential. See page 312 for more information on stairway proportions.

The "Overall Inside Length of Stair Enclosure" figures represent an absolute minimum configuration. Handrail extension requirements may dictate either that the door be recessed into an alcove that falls outside this length or that the length of the stair enclosure be increased in order to satisfy the limitations on obstruction of the width of the landing by the open door. The minimum overall inside width for a stair enclosure is twice the required width of the stair itself, but construction of the stair may be facilitated by increasing this dimension by several inches. Under both the International Building Code and the National Building Code of Canada, the required stairway width is measured from the inside of the stairway or guards, and handrails may project into the required width of the stair for the purposes of computing its occupancy.

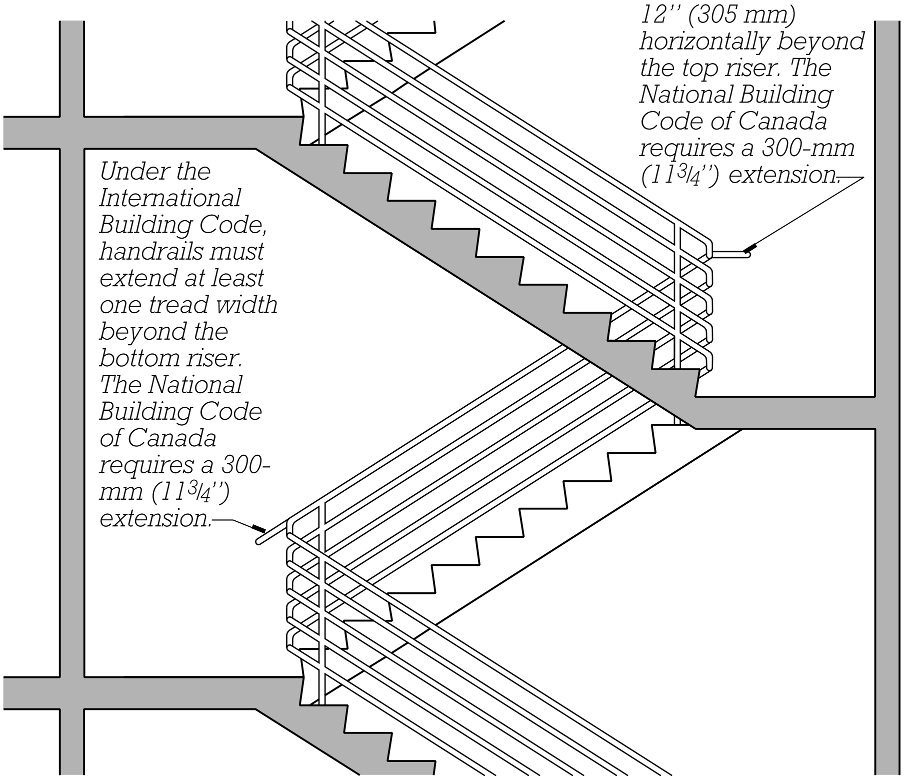
*Under the International Building Code, the door swing must leave at least half the required width of the landing unobstructed, and when fully open the door must not project more than 7'' (178 mm) into the required egress width.*

*Under the National Building Code of Canada, no riser may be located within 300 mm (11¾'') of the leading edge of an exit door throughout its swing.*



*Minimum enclosure width is twice the width of the stair.*

*Under the International Building Code, handrails must extend at least 12'' (305 mm) horizontally beyond the top riser. The National Building Code of Canada requires a 300-mm (11¾'') extension.*



*Under the International Building Code, handrails must extend at least one tread width beyond the bottom riser. The National Building Code of Canada requires a 300-mm (11¾'') extension.*

# EXIT STAIRWAY DESIGN TABLES

## ONE-FLIGHT STAIR: ENGLISH UNITS

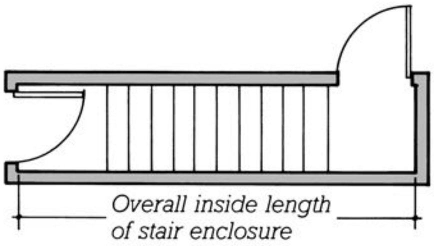
| Floor-to-Floor Height (ft-in.) | Number of Risers | Riser Height (in.) | Tread Depth (in.) | Overall Inside Length of Stair Enclosure (ft-in.) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 36" Width | 44" Width | 56" Width | 66" Width | 88" Width |
| 1-8 | 3 | 6.67 | 11 | 7-10 | 9-2 | 11-2 | 12-10 | 16-6 |
| 2-0 | 4 | 6.00 | 11 | 8-9 | 10-1 | 12-1 | 13-9 | 17-5 |
| 2-4 | 4 | 7.00 | 11 | 8-9 | 10-1 | 12-1 | 13-9 | 17-5 |
| 2-8 | 5 | 6.40 | 11 | 9-8 | 11-0 | 13-0 | 14-8 | 18-4 |
| 3-0 | 6 | 6.00 | 11 | 10-7 | 11-11 | 13-11 | 15-7 | 19-3 |
| 3-4 | 6 | 6.67 | 11 | 10-7 | 11-11 | 13-11 | 15-7 | 19-3 |
| 3-8 | 7 | 6.29 | 11 | 11-6 | 12-10 | 14-10 | 16-6 | 20-2 |
| 4-0 | 7 | 6.86 | 11 | 11-6 | 12-10 | 14-10 | 16-6 | 20-2 |
| 4-4 | 8 | 6.50 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 4-8 | 8 | 7.00 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 5-0 | 9 | 6.67 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 5-4 | 10 | 6.40 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 5-8 | 10 | 6.80 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 6-0 | 11 | 6.55 | 11 | 15-2 | 16-6 | 18-6 | 20-2 | 23-10 |
| 6-4 | 11 | 6.91 | 11 | 15-2 | 16-6 | 18-6 | 20-2 | 23-10 |
| 6-8 | 12 | 6.67 | 11 | 16-1 | 17-5 | 19-5 | 21-1 | 24-9 |
| 7-0 | 12 | 7.00 | 11 | 16-1 | 17-5 | 19-5 | 21-1 | 24-9 |
| 7-4 | 13 | 6.77 | 11 | 17-0 | 18-4 | 20-4 | 22-0 | 25-8 |
| 7-8 | 14 | 6.57 | 11 | 17-11 | 19-3 | 21-3 | 22-0 | 26-7 |
| 8-0 | 14 | 6.86 | 11 | 17-11 | 19-3 | 21-3 | 22-11 | 26-7 |
| 8-4 | 15 | 6.67 | 11 | 18-10 | 20-2 | 22-2 | 23-10 | 27-6 |
| 8-8 | 15 | 6.93 | 11 | 18-10 | 20-2 | 22-2 | 23-10 | 27-6 |
| 9-0 | 16 | 6.75 | 11 | 19-9 | 21-1 | 23-1 | 24-9 | 28-5 |
| 9-4 | 16 | 7.00 | 11 | 19-9 | 21-1 | 23-1 | 24-9 | 28-5 |
| 9-8 | 17 | 6.82 | 11 | 20-8 | 22-0 | 24-0 | 25-8 | 29-4 |
| 10-0 | 18 | 6.67 | 11 | 21-7 | 22-11 | 24-11 | 26-7 | 30-3 |
| 10-4 | 18 | 6.89 | 11 | 21-7 | 22-11 | 24-11 | 26-7 | 30-3 |
| 10-8 | 19 | 6.74 | 11 | 22-6 | 23-10 | 25-10 | 27-6 | 31-2 |
| 11-0 | 19 | 6.95 | 11 | 22-6 | 23-10 | 25-10 | 27-6 | 31-2 |
| 11-4 | 20 | 6.80 | 11 | 23-5 | 24-9 | 26-9 | 28-5 | 32-1 |
| 11-8 | 20 | 7.00 | 11 | 23-5 | 24-9 | 26-9 | 28-5 | 32-1 |
| 12-0 | 21 | 6.86 | 11 | 24-4 | 25-8 | 27-8 | 29-4 | 33-0 |

Stairway widths may be determined rapidly by using the tables and graphs on pages 302–303 and 308–309.

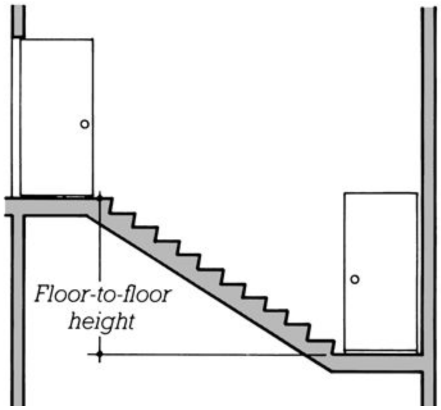
# EXIT STAIRWAY DESIGN TABLES

## ONE-FLIGHT STAIR: METRIC UNITS (280-MM TREAD, 180-MM RISER)

| Floor-to-Floor Height (m) | Number of Risers | Riser Height (mm) | Tread Depth (mm) | Overall Inside Length of Stair Enclosure (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 900-mm Width | 1100-mm Width | 1400-mm Width | 1650-mm Width | 2200-mm Width |
| 0.5 | 3 | 167 | 280 | 2.36 | 2.76 | 3.36 | 3.86 | 4.96 |
| 0.6 | 4 | 150 | 280 | 2.64 | 3.04 | 3.64 | 4.14 | 5.24 |
| 0.7 | 4 | 175 | 280 | 2.64 | 3.04 | 3.64 | 4.14 | 5.24 |
| 0.8 | 5 | 160 | 280 | 2.92 | 3.32 | 3.92 | 4.42 | 5.52 |
| 0.9 | 5 | 180 | 280 | 2.92 | 3.32 | 3.92 | 4.42 | 5.52 |
| 1.0 | 6 | 167 | 280 | 3.20 | 3.60 | 4.20 | 4.70 | 5.80 |
| 1.1 | 7 | 158 | 280 | 3.48 | 3.88 | 4.48 | 4.98 | 6.08 |
| 1.2 | 7 | 172 | 280 | 3.48 | 3.88 | 4.48 | 4.98 | 6.08 |
| 1.3 | 8 | 163 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 1.4 | 8 | 175 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 1.5 | 9 | 167 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 1.6 | 9 | 178 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 1.7 | 10 | 170 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 1.8 | 10 | 180 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 1.9 | 11 | 173 | 280 | 4.60 | 5.00 | 5.60 | 6.10 | 7.20 |
| 2.0 | 12 | 167 | 280 | 4.88 | 5.28 | 5.88 | 6.38 | 7.48 |
| 2.1 | 12 | 175 | 280 | 4.88 | 5.28 | 5.88 | 6.38 | 7.48 |
| 2.2 | 13 | 170 | 280 | 5.16 | 5.56 | 6.16 | 6.66 | 7.76 |
| 2.3 | 13 | 177 | 280 | 5.16 | 5.56 | 6.16 | 6.66 | 7.76 |
| 2.4 | 14 | 172 | 280 | 5.44 | 5.84 | 6.44 | 6.94 | 8.04 |
| 2.5 | 14 | 179 | 280 | 5.44 | 5.84 | 6.44 | 6.94 | 8.04 |
| 2.6 | 15 | 174 | 280 | 5.72 | 6.12 | 6.72 | 7.22 | 8.32 |
| 2.7 | 15 | 180 | 280 | 5.72 | 6.12 | 6.72 | 7.22 | 8.32 |
| 2.8 | 16 | 175 | 280 | 6.00 | 6.40 | 7.00 | 7.50 | 8.60 |
| 2.9 | 17 | 171 | 280 | 6.28 | 6.68 | 7.28 | 7.78 | 8.88 |
| 3.0 | 17 | 177 | 280 | 6.28 | 6.68 | 7.28 | 7.78 | 8.88 |
| 3.1 | 18 | 173 | 280 | 6.56 | 6.96 | 7.56 | 8.06 | 9.16 |
| 3.2 | 18 | 178 | 280 | 6.56 | 6.96 | 7.56 | 8.06 | 9.16 |
| 3.3 | 19 | 174 | 280 | 6.84 | 7.24 | 7.84 | 8.34 | 9.44 |
| 3.4 | 19 | 179 | 280 | 6.84 | 7.24 | 7.84 | 8.34 | 9.44 |
| 3.5 | 20 | 175 | 280 | 7.12 | 7.52 | 8.12 | 8.62 | 9.72 |
| 3.6 | 20 | 180 | 280 | 7.12 | 7.52 | 8.12 | 8.62 | 9.72 |
| 3.7 | 21 | 177 | 280 | 7.40 | 7.80 | 8.40 | 8.90 | 10.00 |



**ONE-FLIGHT STAIR**



# EXIT STAIRWAY DESIGN TABLES

## TWO-FLIGHT STAIR: ENGLISH UNITS

| Floor-to-Floor Height (ft-in.) | Number of Risers | Riser Height (in.) | Tread Depth (in.) | Overall Inside Length of Stair Enclosure (ft-in.) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 36" Width | 44" Width | 56" Width | 66" Width | 88" Width |
| 7-8[a] | 14 | 6.57 | 11 | 11-6 | 12-10 | 14-10 | 16-6 | 20-2 |
| 8-0[a] | 14 | 6.86 | 11 | 11-6 | 12-10 | 14-10 | 16-6 | 20-2 |
| 8-4 | 15 | 6.67 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 8-8 | 15 | 6.93 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 9-0 | 16 | 6.75 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 9-4 | 16 | 7.00 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 9-8 | 17 | 6.82 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 10-0 | 18 | 6.67 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 10-4 | 18 | 6.89 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 10-8 | 19 | 6.74 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 11-0 | 19 | 6.95 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 11-4 | 20 | 6.80 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 11-8 | 20 | 7.00 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 12-0 | 21 | 6.86 | 11 | 15-2 | 16-6 | 18-6 | 20-2 | 23-10 |
| 12-4 | 22 | 6.73 | 11 | 15-2 | 16-6 | 18-6 | 20-2 | 23-10 |
| 12-8 | 22 | 6.91 | 11 | 15-2 | 16-6 | 18-6 | 20-2 | 23-10 |
| 13-0 | 23 | 6.78 | 11 | 16-1 | 17-5 | 19-5 | 21-1 | 24-9 |
| 13-4 | 23 | 6.96 | 11 | 16-1 | 17-5 | 19-5 | 21-1 | 24-9 |
| 13-8 | 24 | 6.83 | 11 | 16-1 | 17-5 | 19-5 | 21-1 | 24-9 |
| 14-0 | 24 | 7.00 | 11 | 16-1 | 17-5 | 19-5 | 21-1 | 24-9 |
| 14-4 | 25 | 6.88 | 11 | 17-0 | 18-4 | 20-4 | 22-0 | 25-8 |
| 14-8 | 26 | 6.77 | 11 | 17-0 | 18-4 | 20-4 | 22-0 | 25-8 |
| 15-0 | 26 | 6.92 | 11 | 17-0 | 18-4 | 20-4 | 22-0 | 25-8 |
| 16-0 | 28 | 6.86 | 11 | 17-11 | 19-3 | 21-3 | 22-11 | 26-7 |
| 17-0 | 30 | 6.80 | 11 | 18-10 | 20-2 | 22-2 | 23-10 | 27-6 |
| 18-0 | 31 | 6.97 | 11 | 19-9 | 21-1 | 23-1 | 24-9 | 28-5 |
| 19-0 | 33 | 6.91 | 11 | 20-8 | 22-0 | 24-0 | 25-8 | 29-4 |
| 20-0 | 35 | 6.86 | 11 | 21-7 | 22-11 | 24-11 | 26-7 | 30-3 |
| 21-0 | 36 | 7.00 | 11 | 21-7 | 22-11 | 24-11 | 26-7 | 30-3 |
| 22-0 | 38 | 6.95 | 11 | 22-6 | 23-10 | 25-10 | 27-6 | 31-2 |
| 23-0 | 40 | 6.90 | 11 | 23-5 | 24-9 | 26-9 | 28-5 | 32-1 |
| 24-0 | 42 | 6.86 | 11 | 24-4 | 25-8 | 27-8 | 29-4 | 33-0 |

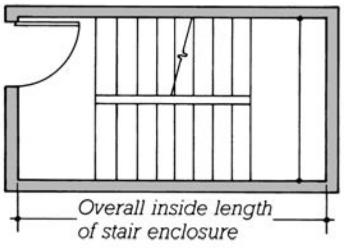
[a] The headroom in these stairs may be deficient, depending on the detailing of the stair structure.

Stairway widths may be determined rapidly by using the tables and graphs on pages 302–303 and 308–309.

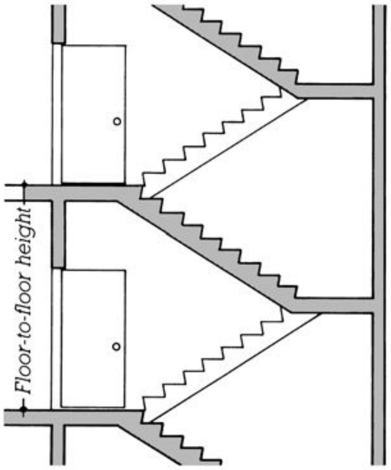
# EXIT STAIRWAY DESIGN TABLES

## TWO-FLIGHT STAIR: METRIC UNITS (280-MM TREAD, MAXIMUM 180-MM RISER)

| Floor-to-Floor Height (m) | Number of Risers | Riser Height (mm) | Tread Depth (mm) | Overall Inside Length of Stair Enclosure (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 900-mm Width | 1100-mm Width | 1400-mm Width | 1650-mm Width | 2200-mm Width |
| 2.3 | 13 | 177 | 280 | 3.48 | 3.88 | 4.48 | 4.98 | 6.08 |
| 2.4 | 14 | 172 | 280 | 3.48 | 3.88 | 4.48 | 4.98 | 6.08 |
| 2.5 | 14 | 179 | 280 | 3.48 | 3.88 | 4.48 | 4.98 | 6.08 |
| 2.6 | 15 | 174 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 2.7 | 15 | 180 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 2.8 | 16 | 175 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 2.9 | 17 | 171 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 3.0 | 17 | 177 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 3.1 | 18 | 173 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 3.2 | 18 | 178 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 3.3 | 19 | 174 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 3.4 | 19 | 179 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 3.5 | 20 | 175 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 3.6 | 20 | 180 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 3.7 | 21 | 177 | 280 | 4.60 | 5.00 | 5.60 | 6.10 | 7.20 |
| 3.8 | 22 | 173 | 280 | 4.60 | 5.00 | 5.60 | 6.10 | 7.20 |
| 3.9 | 22 | 178 | 280 | 4.60 | 5.00 | 5.60 | 6.10 | 7.20 |
| 4.0 | 23 | 174 | 280 | 4.88 | 5.28 | 5.88 | 6.38 | 7.48 |
| 4.1 | 23 | 179 | 280 | 4.88 | 5.28 | 5.88 | 6.38 | 7.48 |
| 4.2 | 24 | 175 | 280 | 4.88 | 5.28 | 5.88 | 6.38 | 7.48 |
| 4.3 | 24 | 180 | 280 | 4.88 | 5.28 | 5.88 | 6.38 | 7.48 |
| 4.4 | 25 | 176 | 280 | 5.16 | 5.56 | 6.16 | 6.66 | 7.76 |
| 4.5 | 25 | 180 | 280 | 5.16 | 5.56 | 6.16 | 6.66 | 7.76 |
| 4.8 | 27 | 178 | 280 | 5.44 | 5.84 | 6.44 | 6.94 | 8.04 |
| 5.1 | 29 | 176 | 280 | 5.72 | 6.12 | 6.72 | 7.22 | 8.32 |
| 5.4 | 30 | 180 | 280 | 5.72 | 6.12 | 6.72 | 7.22 | 8.32 |
| 5.7 | 32 | 179 | 280 | 6.00 | 6.40 | 7.00 | 7.50 | 8.60 |
| 6.0 | 34 | 177 | 280 | 6.28 | 6.68 | 7.28 | 7.78 | 8.88 |
| 6.3 | 35 | 180 | 280 | 6.56 | 6.96 | 7.56 | 8.06 | 9.16 |
| 6.6 | 37 | 179 | 280 | 6.84 | 7.24 | 7.84 | 8.34 | 9.44 |
| 6.9 | 39 | 177 | 280 | 7.12 | 7.52 | 8.12 | 8.62 | 9.72 |
| 7.2 | 40 | 180 | 280 | 7.12 | 7.52 | 8.12 | 8.62 | 9.72 |
| 7.4 | 42 | 177 | 280 | 7.40 | 7.80 | 8.40 | 8.90 | 100 |



**TWO-FLIGHT STAIR**



### THREE-FLIGHT STAIR: ENGLISH UNITS

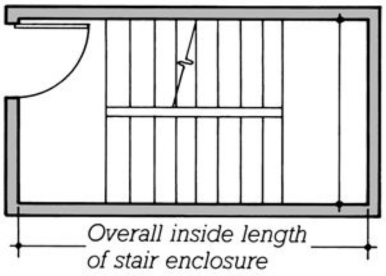
| Floor-to-Floor Height (ft-in.) | Number of Risers | Riser Height (in.) | Tread Depth (in.) | Overall Inside Length of Stair Enclosure (ft-in.) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 36" Width | 44" Width | 56" Width | 66" Width | 88" Width |
| 12-0 | 21 | 6.86 | 11 | 11-6 | 12-10 | 14-10 | 16-6 | 20-2 |
| 12-4 | 22 | 6.73 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 12-8 | 22 | 6.91 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 13-0 | 23 | 6.78 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 13-4 | 23 | 6.96 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 13-8 | 24 | 6.83 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 14-0 | 24 | 7.00 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 14-4 | 25 | 6.88 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 14-8 | 26 | 6.77 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 15-0 | 26 | 6.92 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 16-0 | 28 | 6.86 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 17-0 | 30 | 6.80 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 18-0 | 31 | 6.97 | 11 | 15-2 | 16-6 | 18-6 | 20-2 | 23-10 |
| 19-0 | 33 | 6.91 | 11 | 15-2 | 16-6 | 18-6 | 20-2 | 23-10 |
| 20-0 | 35 | 6.86 | 11 | 16-1 | 17-5 | 19-5 | 21-1 | 24-9 |
| 21-0 | 36 | 7.00 | 11 | 16-1 | 17-5 | 19-5 | 21-1 | 24-9 |
| 22-0 | 38 | 6.95 | 11 | 17-0 | 18-4 | 20-4 | 22-0 | 25-8 |
| 23-0 | 40 | 6.90 | 11 | 17-11 | 19-3 | 21-3 | 22-11 | 26-7 |
| 24-0 | 42 | 6.86 | 11 | 17-11 | 19-3 | 21-3 | 22-11 | 26-7 |

Stairway widths may be determined rapidly by using the tables and graphs on pages 302–303 and 308–309.

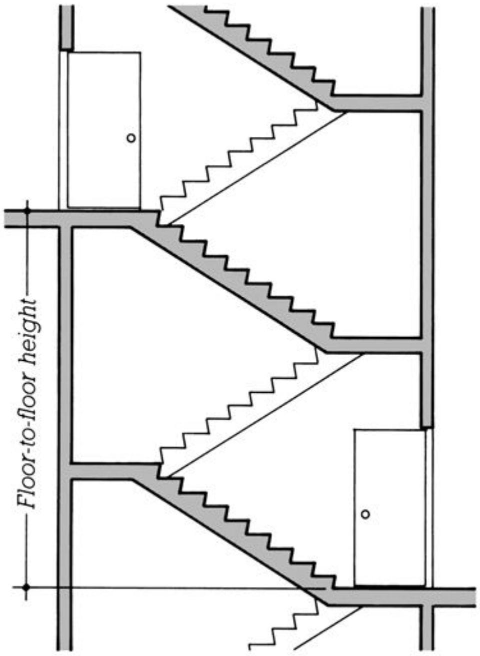
# EXIT STAIRWAY DESIGN TABLES

### THREE-FLIGHT STAIR: METRIC UNITS (280-MM TREAD, MAXIMUM 180-MM RISER)

| Floor-to-Floor Height (m) | Number of Risers | Riser Height (mm) | Tread Depth (mm) | Overall Inside Length of Stair Enclosure (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 900-mm Width | 1100-mm Width | 1400-mm Width | 1650-mm Width | 2200-mm Width |
| 3.6 | 20 | 180 | 280 | 3.48 | 3.88 | 4.48 | 4.98 | 6.08 |
| 3.7 | 21 | 177 | 280 | 3.48 | 3.88 | 4.48 | 4.98 | 6.08 |
| 3.8 | 22 | 173 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 3.9 | 22 | 178 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 4.0 | 23 | 174 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 4.1 | 23 | 179 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 4.2 | 24 | 175 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 4.3 | 24 | 180 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 4.4 | 25 | 176 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 4.5 | 25 | 180 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 4.8 | 27 | 178 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 5.1 | 29 | 176 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 5.4 | 30 | 180 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 5.7 | 32 | 179 | 280 | 4.60 | 5.00 | 5.60 | 6.10 | 7.20 |
| 6.0 | 34 | 177 | 280 | 4.88 | 5.28 | 5.88 | 6.38 | 7.48 |
| 6.3 | 35 | 180 | 280 | 4.88 | 5.28 | 5.88 | 6.38 | 7.48 |
| 6.6 | 37 | 179 | 280 | 5.16 | 5.56 | 6.16 | 6.66 | 7.76 |
| 6.9 | 39 | 177 | 280 | 5.16 | 5.56 | 6.16 | 6.66 | 7.76 |
| 7.2 | 40 | 180 | 280 | 5.44 | 5.84 | 6.44 | 6.94 | 8.04 |
| 7.4 | 42 | 177 | 280 | 5.44 | 5.84 | 6.44 | 6.94 | 8.04 |



**THREE-FLIGHT STAIR**



## FOUR-FLIGHT STAIR: ENGLISH UNITS

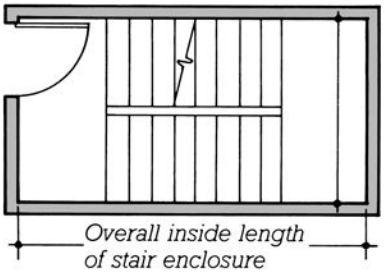
| Floor-to-Floor Height (ft-in.) | Number of Risers | Riser Height (in.) | Tread Depth (in.) | Overall Inside Length of Stair Enclosure (ft-in.) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 36" Width | 44" Width | 56" Width | 66" Width | 88" Width |
| 16-0 | 28 | 6.86 | 11 | 11-6 | 12-10 | 14-10 | 16-6 | 20-2 |
| 17-0 | 30 | 6.80 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 18-0 | 31 | 6.97 | 11 | 12-5 | 13-9 | 15-9 | 17-5 | 21-1 |
| 19-0 | 33 | 6.91 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 20-0 | 35 | 6.86 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 21-0 | 36 | 7.00 | 11 | 13-4 | 14-8 | 16-8 | 18-4 | 22-0 |
| 22-0 | 38 | 6.95 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 23-0 | 40 | 6.90 | 11 | 14-3 | 15-7 | 17-7 | 19-3 | 22-11 |
| 24-0 | 42 | 6.86 | 11 | 15-2 | 16-6 | 18-6 | 20-2 | 23-10 |

Stairway widths may be determined rapidly by using the tables and graphs on pages 302–303 and 308–309.

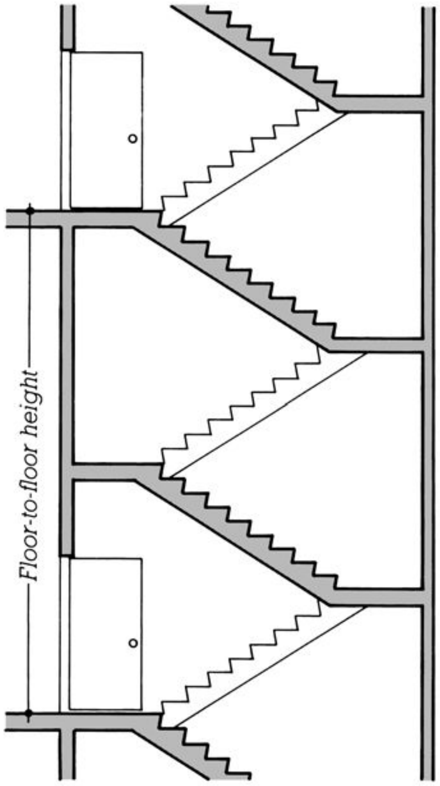
# EXIT STAIRWAY DESIGN TABLES

### FOUR-FLIGHT STAIR: METRIC UNITS (280-MM TREAD, MAXIMUM 180-MM RISER)

| Floor-to-Floor Height (m) | Number of Risers | Riser Height (mm) | Tread Depth (mm) | Overall Inside Length of Stair Enclosure (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 900-mm Width | 1100-mm Width | 1400-mm Width | 1650-mm Width | 2200-mm Width |
| 4.8 | 27 | 178 | 280 | 3.48 | 3.88 | 4.48 | 4.98 | 6.08 |
| 5.1 | 29 | 176 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 5.4 | 30 | 180 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 5.7 | 32 | 179 | 280 | 3.76 | 4.16 | 4.76 | 5.26 | 6.36 |
| 6.0 | 34 | 177 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 6.3 | 35 | 180 | 280 | 4.04 | 4.44 | 5.04 | 5.54 | 6.64 |
| 6.6 | 37 | 179 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 6.9 | 39 | 177 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 7.2 | 40 | 180 | 280 | 4.32 | 4.72 | 5.32 | 5.82 | 6.92 |
| 7.4 | 42 | 177 | 280 | 4.60 | 5.00 | 5.60 | 6.10 | 7.20 |



**FOUR-FLIGHT STAIR**



### DOUGHNUT STAIR: ENGLISH UNITS

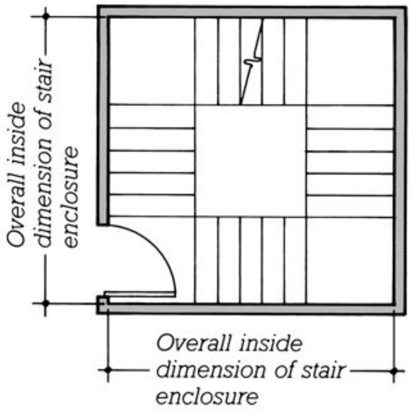
| Floor-to-Floor Height (ft-in.) | Number of Risers | Riser Height (in.) | Tread Depth (in.) | Overall Inside Length of Stair Enclosure (ft-in.) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 36" Width | 44" Width | 56" Width | 66" Width | 88" Width |
| 7-8 | 14 | 6.57 | 11 | 7-10 × 8-9 | 9-2 × 10-1 | 11-2 × 12-1 | 12-10 × 13-9 | 16-6 × 17-5 |
| 8-0 | 14 | 6.86 | 11 | 7-10 × 8-9 | 9-2 × 10-1 | 11-2 × 12-1 | 12-10 × 13-9 | 16-6 × 17-5 |
| 8-4 | 15 | 6.67 | 11 | 8-9 × 8-9 | 10-1 × 10-1 | 12-1 × 12-1 | 13-9 × 13-9 | 17-5 × 17-5 |
| 8-8 | 15 | 6.93 | 11 | 8-9 × 8-9 | 10-1 × 10-1 | 12-1 × 12-1 | 13-9 × 13-9 | 17-5 × 17-5 |
| 9-0 | 16 | 6.75 | 11 | 8-9 × 8-9 | 10-1 × 10-1 | 12-1 × 12-1 | 13-9 × 13-9 | 17-5 × 17-5 |
| 9-4 | 16 | 7.00 | 11 | 8-9 × 8-9 | 10-1 × 10-1 | 12-1 × 12-1 | 13-9 × 13-9 | 17-5 × 17-5 |
| 9-8 | 17 | 6.82 | 11 | 8-9 × 9-8 | 10-1 × 11-0 | 12-1 × 13-0 | 13-9 × 14-8 | 17-5 × 18-4 |
| 10-0 | 18 | 6.67 | 11 | 8-9 × 9-8 | 10-1 × 11-0 | 12-1 × 13-0 | 13-9 × 14-8 | 17-5 × 18-4 |
| 10-4 | 18 | 6.89 | 11 | 8-9 × 9-8 | 10-1 × 11-0 | 12-1 × 13-0 | 13-9 × 14-8 | 17-5 × 18-4 |
| 10-8 | 19 | 6.74 | 11 | 9-8 × 9-8 | 11-0 × 11-0 | 13-0 × 13-0 | 14-8 × 14-8 | 18-4 × 18-4 |
| 11-0 | 19 | 6.95 | 11 | 9-8 × 9-8 | 11-0 × 11-0 | 13-0 × 13-0 | 14-8 × 14-8 | 18-4 × 18-4 |
| 11-4 | 20 | 6.80 | 11 | 9-8 × 9-8 | 11-0 × 11-0 | 13-0 × 13-0 | 14-8 × 14-8 | 18-4 × 18-4 |
| 11-8 | 20 | 7.00 | 11 | 9-8 × 9-8 | 11-0 × 11-0 | 13-0 × 13-0 | 14-8 × 14-8 | 18-4 × 18-4 |
| 12-0 | 21 | 6.86 | 11 | 9-8 × 10-7 | 11-0 × 11-11 | 13-0 × 13-11 | 14-8 × 15-7 | 18-4 × 19-3 |
| 12-4 | 22 | 6.73 | 11 | 9-8 × 10-7 | 11-0 × 11-11 | 13-0 × 13-11 | 14-8 × 15-7 | 18-4 × 19-3 |
| 12-8 | 22 | 6.91 | 11 | 9-8 × 10-7 | 11-0 × 11-11 | 13-0 × 13-11 | 14-8 × 15-7 | 18-4 × 19-3 |
| 13-0 | 23 | 6.78 | 11 | 10-7 × 10-7 | 11-11 × 11-11 | 13-11 × 13-11 | 15-7 × 15-7 | 19-3 × 19-3 |
| 13-4 | 23 | 6.96 | 11 | 10-7 × 10-7 | 11-11 × 11-11 | 13-11 × 13-11 | 15-7 × 15-7 | 19-3 × 19-3 |
| 13-8 | 24 | 6.83 | 11 | 10-7 × 10-7 | 11-11 × 11-11 | 13-11 × 13-11 | 15-7 × 15-7 | 19-3 × 19-3 |
| 14-0 | 24 | 7.00 | 11 | 10-7 × 10-7 | 11-11 × 11-11 | 13-11 × 13-11 | 15-7 × 15-7 | 19-3 × 19-3 |
| 14-4 | 25 | 6.88 | 11 | 10-7 × 11-6 | 11-11 × 12-10 | 13-11 × 14-10 | 15-7 × 16-6 | 19-3 × 20-2 |
| 14-8 | 26 | 6.77 | 11 | 10-7 × 11-6 | 11-11 × 12-10 | 13-11 × 14-10 | 15-7 × 16-6 | 19-3 × 20-2 |
| 15-0 | 26 | 6.92 | 11 | 10-7 × 11-6 | 11-11 × 12-10 | 13-11 × 14-10 | 15-7 × 16-6 | 19-3 × 20-2 |
| 16-0 | 28 | 6.86 | 11 | 11-6 × 11-6 | 12-10 × 12-10 | 14-10 × 14-10 | 16-6 × 16-6 | 20-2 × 20-2 |
| 17-0 | 30 | 6.80 | 11 | 11-6 × 12-5 | 12-10 × 13-9 | 14-10 × 15-9 | 16-6 × 17-5 | 20-2 × 21-1 |
| 18-0 | 31 | 6.97 | 11 | 12-5 × 12-5 | 13-9 × 13-9 | 15-9 × 15-9 | 17-5 × 17-5 | 21-1 × 21-1 |
| 19-0 | 33 | 6.91 | 11 | 12-5 × 13-4 | 13-9 × 14-8 | 15-9 × 16-8 | 17-5 × 18-4 | 21-1 × 22-0 |
| 20-0 | 35 | 6.86 | 11 | 13-4 × 13-4 | 14-8 × 14-8 | 16-8 × 16-8 | 18-4 × 18-4 | 22-0 × 22-0 |
| 21-0 | 36 | 7.00 | 11 | 13-4 × 13-4 | 14-8 × 14-8 | 16-8 × 16-8 | 18-4 × 18-4 | 22-0 × 22-0 |
| 22-0 | 38 | 6.95 | 11 | 13-4 × 14-3 | 14-8 × 15-7 | 16-8 × 17-7 | 18-4 × 19-3 | 22-0 × 22-11 |
| 23-0 | 40 | 6.90 | 11 | 14-3 × 14-3 | 15-7 × 15-7 | 17-7 × 17-7 | 19-3 × 19-3 | 22-11 × 22-11 |
| 24-0 | 42 | 6.86 | 11 | 14-3 × 15-2 | 15-7 × 16-6 | 17-7 × 18-6 | 19-3 × 20-2 | 22-11 × 23-10 |

Stairway widths may be determined rapidly by using the tables and graphs on pages 302–303 and 308–309.

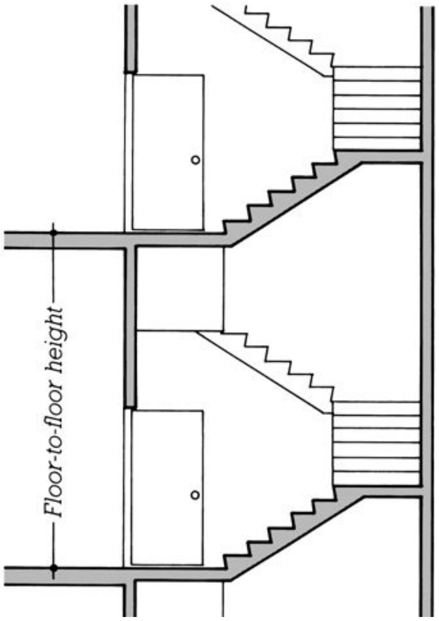
# EXIT STAIRWAY DESIGN TABLES

### DOUGHNUT STAIR: METRIC UNITS (280-MM TREAD, 180-MM RISER)

| Floor-to-Floor Height (m) | Number of Risers | Riser Height (mm) | Tread Depth (mm) | Overall Inside Length of Stair Enclosure (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 900-mm Width | 1100-mm Width | 1400-mm Width | 1650-mm Width | 2200-mm Width |
| 2.3 | 13 | 177 | 280 | 2.36 × 2.64 | 2.76 × 3.04 | 3.36 × 3.64 | 3.86 × 4.14 | 4.96 × 5.24 |
| 2.4 | 14 | 172 | 280 | 2.36 × 2.64 | 2.76 × 3.04 | 3.36 × 3.64 | 3.86 × 4.14 | 4.96 × 5.24 |
| 2.5 | 14 | 179 | 280 | 2.36 × 2.64 | 2.76 × 3.04 | 3.36 × 3.64 | 3.86 × 4.14 | 4.96 × 5.24 |
| 2.6 | 15 | 174 | 280 | 2.64 × 2.64 | 3.04 × 3.04 | 3.64 × 3.64 | 4.14 × 4.14 | 5.24 × 5.24 |
| 2.7 | 15 | 180 | 280 | 2.64 × 2.64 | 3.04 × 3.04 | 3.64 × 3.64 | 4.14 × 4.14 | 5.24 × 5.24 |
| 2.8 | 16 | 175 | 280 | 2.64 × 2.64 | 3.04 × 3.04 | 3.64 × 3.64 | 4.14 × 4.14 | 5.24 × 5.24 |
| 2.9 | 17 | 171 | 280 | 2.64 × 2.92 | 3.04 × 3.32 | 3.64 × 3.92 | 4.14 × 4.42 | 5.24 × 5.52 |
| 3.0 | 17 | 177 | 280 | 2.64 × 2.92 | 3.04 × 3.32 | 3.64 × 3.92 | 4.14 × 4.42 | 5.24 × 5.52 |
| 3.1 | 18 | 173 | 280 | 2.64 × 2.92 | 3.04 × 3.32 | 3.64 × 3.92 | 4.14 × 4.42 | 5.24 × 5.52 |
| 3.2 | 18 | 178 | 280 | 2.64 × 2.92 | 3.04 × 3.32 | 3.64 × 3.92 | 4.14 × 4.42 | 5.24 × 5.52 |
| 3.3 | 19 | 174 | 280 | 2.92 × 2.92 | 3.32 × 3.32 | 3.92 × 3.92 | 4.42 × 4.42 | 5.52 × 5.52 |
| 3.4 | 19 | 179 | 280 | 2.92 × 2.92 | 3.32 × 3.32 | 3.92 × 3.92 | 4.42 × 4.42 | 5.52 × 5.52 |
| 3.5 | 20 | 175 | 280 | 2.92 × 2.92 | 3.32 × 3.32 | 3.92 × 3.92 | 4.42 × 4.42 | 5.52 × 5.52 |
| 3.6 | 20 | 180 | 280 | 2.92 × 2.92 | 3.32 × 3.32 | 3.92 × 3.92 | 4.42 × 4.42 | 5.52 × 5.52 |
| 3.7 | 21 | 177 | 280 | 2.92 × 3.20 | 3.32 × 3.60 | 3.92 × 4.20 | 4.42 × 4.70 | 5.52 × 5.80 |
| 3.8 | 22 | 173 | 280 | 2.92 × 3.20 | 3.32 × 3.60 | 3.92 × 4.20 | 4.42 × 4.70 | 5.52 × 5.80 |
| 3.9 | 22 | 178 | 280 | 2.92 × 3.20 | 3.32 × 3.60 | 3.92 × 4.20 | 4.42 × 4.70 | 5.52 × 5.80 |
| 4.0 | 23 | 174 | 280 | 3.20 × 3.20 | 3.60 × 3.60 | 4.20 × 4.20 | 4.70 × 4.70 | 5.80 × 5.80 |
| 4.1 | 23 | 179 | 280 | 3.20 × 3.20 | 3.60 × 3.60 | 4.20 × 4.20 | 4.70 × 4.70 | 5.80 × 5.80 |
| 4.2 | 24 | 175 | 280 | 3.20 × 3.20 | 3.60 × 3.60 | 4.20 × 4.20 | 4.70 × 4.70 | 5.80 × 5.80 |
| 4.3 | 24 | 180 | 280 | 3.20 × 3.20 | 3.60 × 3.60 | 4.20 × 4.20 | 4.70 × 4.70 | 5.80 × 5.80 |
| 4.4 | 25 | 176 | 280 | 3.20 × 3.48 | 3.60 × 3.88 | 4.20 × 4.48 | 4.70 × 4.98 | 5.80 × 6.08 |
| 4.5 | 25 | 180 | 280 | 3.20 × 3.48 | 3.60 × 3.88 | 4.20 × 4.48 | 4.70 × 4.98 | 5.80 × 6.08 |
| 4.8 | 27 | 178 | 280 | 3.48 × 3.48 | 3.88 × 3.88 | 4.48 × 4.48 | 4.98 × 4.98 | 6.08 × 6.08 |
| 5.1 | 29 | 176 | 280 | 3.48 × 3.76 | 3.88 × 4.16 | 4.48 × 4.76 | 4.98 × 5.26 | 6.08 × 6.36 |
| 5.4 | 30 | 180 | 280 | 3.48 × 3.76 | 3.88 × 4.16 | 4.48 × 4.76 | 4.98 × 5.26 | 6.08 × 6.36 |
| 5.7 | 32 | 179 | 280 | 3.76 × 3.76 | 4.16 × 4.16 | 4.76 × 4.76 | 5.26 × 5.26 | 6.36 × 6.36 |
| 6.0 | 34 | 177 | 280 | 3.76 × 4.04 | 4.16 × 4.44 | 4.76 × 5.04 | 5.26 × 5.54 | 6.36 × 6.64 |
| 6.3 | 35 | 180 | 280 | 4.04 × 4.04 | 4.44 × 4.44 | 5.04 × 5.04 | 5.54 × 5.54 | 6.64 × 6.64 |
| 6.6 | 37 | 179 | 280 | 4.04 × 4.32 | 4.44 × 4.72 | 5.04 × 5.32 | 5.54 × 5.82 | 6.64 × 6.92 |
| 6.9 | 39 | 177 | 280 | 4.32 × 4.32 | 4.72 × 4.72 | 5.32 × 5.32 | 5.82 × 5.82 | 6.92 × 6.92 |
| 7.2 | 40 | 180 | 280 | 4.32 × 4.32 | 4.72 × 4.72 | 5.32 × 5.32 | 5.82 × 5.82 | 6.92 × 6.92 |
| 7.4 | 42 | 177 | 280 | 4.32 × 4.60 | 4.72 × 5.00 | 5.32 × 5.60 | 5.82 × 6.10 | 6.92 × 7.20 |



**DOUGHNUT STAIR**



SECTION

# 6

# DESIGNING FOR PARKING

# 1

# DESIGN CRITERIA FOR PARKING FACILITIES

***This chapter will help you select an appropriate type of parking facility and establish criteria for its capacity, level of amenity, and accessibility. For facilities other than surface parking, it will also assist you in the selection and configuration of a structural system.***

# PARKING FACILITY TYPES

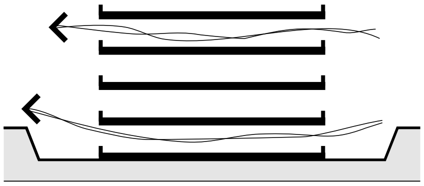
*Surface parking* is constructed solely at grade. It is the least expensive form of parking, requiring little more than site preparation, paving, and related improvements. Surface parking is the most land-use intensive of all parking types and also the most common type, comprising more than two-thirds of all parking in the United States.

*Structured parking* consists of parking contained within enclosed or open buildings. In comparison to surface parking, structured parking consumes less land. However, the required building structure adds significant cost. Structured parking is normally chosen where the high cost or limited availability of land make surface parking uneconomical or impractical. Structured parking is also a better choice for very large parking facilities where the walking distance from parking stalls to the facility served becomes uncomfortably long in a surface parking solution.

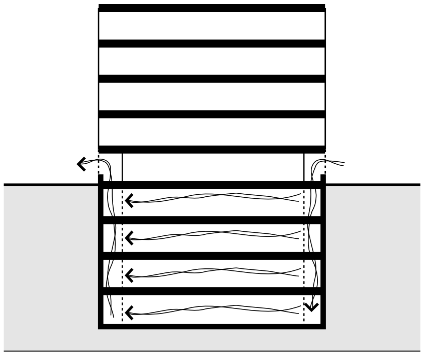
Structured parking can be open or enclosed. *Open parking* relies on natural ventilation to prevent the dangerous accumulation of toxic exhaust gasses or flammable vapors within the structure.

Where natural ventilation is not a practical option, parking may be contained in mechanically ventilated structures called *enclosed parking*. Because of the added expense of the mechanical systems and a complete building enclosure, enclosed parking structures are more expensive than open ones. Enclosed parking may be constructed above or below grade. Above-grade structures are designed as enclosed rather than open when natural ventilation is not practical, such as where exterior walls abut other buildings or are too close to permit the extensive openings required for an open garage. Wherever parking is constructed substantially below grade, enclosed parking is the only choice, since natural ventilation is not feasible. Because of the significant added costs associated with excavation and other aspects of below-ground construction, enclosed below-grade parking is the most expensive form of conventional parking facility. On the other hand, from a resource conservation point of view, it may also consume the least land of any conventional type of parking facility.

*Automated parking* is a specialized type of structured parking in which vehicles are transported within the facility on specially designed lifting and conveying equipment rather than through a conventional system of drivable ramps and parking aisles. The additional expense of the conveying systems in these facilities is offset by their ability to store roughly twice as many vehicles as a conventional facility of equal size. Automated parking facilities may also offer advantages in improved car security, lower staffing costs, and more rapid vehicle delivery than conventional facilities. They are most economically attractive in locations with very high land costs or on highly constrained sites. This chapter does not provide design guidelines for this type of facility; manufacturers of automated parking facility equipment should be consulted for more information.



**OPEN PARKING STRUCTURE WITH NATURAL VENTILATION**



**ENCLOSED BELOW-GRADE PARKING STRUCTURE WITH MECHANICAL VENTILATION**

In summary, listed in order from lowest to highest cost, the choice of parking facility type is typically as follows:

- Surface parking
- Open parking structure, above grade
- Enclosed parking structure, above grade
- Enclosed parking structure, below grade
- Automated parking facility

## PARKING CAPACITY

The planned capacity of a parking facility, that is, the number of parking stalls that will be provided, may be dictated by local land-use regulations or other ordinances, or it may be established on the basis of anticipated demand, reflecting the parking needs of the facilities to be served. Ordinances that dictate parking requirements are not addressed in this chapter, as they are unique to each locality. The designer should always seek out such information and verify the regulatory requirements for his or her project at the earliest possible stage of design.

Where parking capacity is based on estimates of demand, factors to be considered may include the types of facilities being served, analyses of comparable sites, expected peak and average parking volumes, level of service expectations, anticipated use patterns, the impact of nearby existing or planned parking facilities, area traffic studies, the availability of alternative transportation, and area economic and development projections. Since the combination of such factors is unique to any location, no one set of parking demand figures can be applied universally to all sites. However, where location-specific information is not available or has not yet been developed, the recommended parking ratios provided in the table on this page may be used for preliminary design purposes.

| **Type of Use Served by Parking** | **Recommended Parking Ratios for Preliminary Design (1000 gross ft$^2$ = 93 m$^2$ gross)** |
|---|---|
| Assembly Spaces such as theaters, arenas, cinemas, etc. | 0.25 to 0.5 spaces per seat or occupant |
| Convenience Stores | 2–10 per 1000 gross ft$^2$ |
| Convention Centers | 20 per 1000 gross ft$^2$ |
| Hospitals and Medical Centers | The sum of:<br>0.1–0.75 per staff, plus<br>0.3–0.75 per bed, plus<br>0.2 per daily outpatient<br>Or: 4–10 per 1000 gross ft$^2$ |
| Hotels | The sum of:<br>0.2–1.5 spaces per room, plus<br>10–20 per 1000 gross ft$^2$ of public space and meeting rooms |
| Industrial Facilities | 0.5–4 per 1000 gross ft$^2$ |
| Office Buildings | 0.5–3 per 1000 gross ft$^2$ |
| Residential, Single-Family | 1–2 spaces per dwelling unit |
| Residential, Multifamily | 0.5–2 spaces per dwelling unit |
| Restaurants | 10–25 per 1000 gross ft$^2$ |
| Retail | 2–4 per 1000 gross ft$^2$ |
| Schools K–12 | The sum of:<br>1–1.5 per classroom, plus<br>0.25 per driving age student |
| Shopping Centers, Malls | 4–6 per 1000 gross ft$^2$ |
| Universities | The sum of:<br>0.1–0.5 spaces per student, and<br>0.8 spaces per staff |

## FACILITY LEVEL OF SERVICE

Parking facility design allows trade-offs between user convenience and comfort, on the one hand, and the economy and compactness of the facility, on the other. For example, the optimal size of a stall in a parking garage built in a dense urban setting, where space is at a premium and users are accustomed to constrained parking conditions, may be significantly smaller than that of a stall in a suburban shopping center, where land costs are lower and user amenity is a higher priority. Similar trade-offs may be made for the width of driving lanes, turning radii, floor-to-ceiling heights, driving and walking distances within the facility, traffic flow capacity, wait times at entrances and exits, and other aspects of the facility's design.

In this chapter, parking facilities are classified according to four *levels of service*, A through D. Level of Service A describes conditions that place the highest priority on user comfort and convenience; Level of Service D describes those placing the greatest emphasis on economy and the efficient utilization of space; and Levels of Service B and C represent intermediate conditions. In choosing a level of service for your project, the most important criteria are the familiarity of the user with the facility (familiar users can comfortably

# PARKING CAPACITY AND LEVEL OF SERVICE

tolerate lower level of service conditions), the rate of parking turnover (with more vehicles moving through a facility at any given time, more generous dimensions should be provided to avoid conflicts or bottlenecks), and the expectations of the user (users accustomed to constrained parking conditions will be more tolerant of lower level of service conditions). Additional factors that may be considered in choosing the level of service for a facility include the following. Consider higher level of service designations for:

- Parking facilities in which users will frequently be carrying bulky packages or large materials
- Facilities used by the elderly or infirm
- Facilities serving family-oriented activities
- Outdoor parking in cold climate regions, where users wearing bulky clothing may have greater difficulty entering and exiting cars during periods of inclement weather
- Parking located in rural or suburban places where drivers are accustomed to readily available, less constrained parking

Lower level of service designations may be appropriate for:

- All-day or long-term parking
- Employee parking, residential parking, and other parking for repeat users who will be familiar with a facility
- Parking located in dense urban areas, where users are accustomed to congested traffic conditions and limited availability of parking

The following table provides recommended level of service ranges for parking serving various types of uses.

| | **Recommended Level of Service (LOS) Range** | | | |
|---|---|---|---|---|
| **Type of Use Served by Parking** | **LOS A** | **LOS B** | **LOS C** | **LOS D** |
| Airports, Transportation Centers, all day and long-term | | ━ | ━ | ━ |
| Airports, Transportation Centers, short-term | ━ | ━ | | |
| Assembly Spaces such as theaters, sports arenas, cinemas, etc. | ━ | ━ | | |
| Convention Centers | ━ | ━ | | |
| Hospitals and Medical Centers | ━ | ━ | | |
| Hotels | | ━ | ━ | |
| Industrial Facilities | | | ━ | ━ |
| Office Buildings | | ━ | ━ | |
| Residential | | | ━ | ━ |
| Retail, Shopping Centers | ━ | ━ | | |
| Schools K-12 | | ━ | ━ | |
| Universities | | ━ | ━ | ━ |

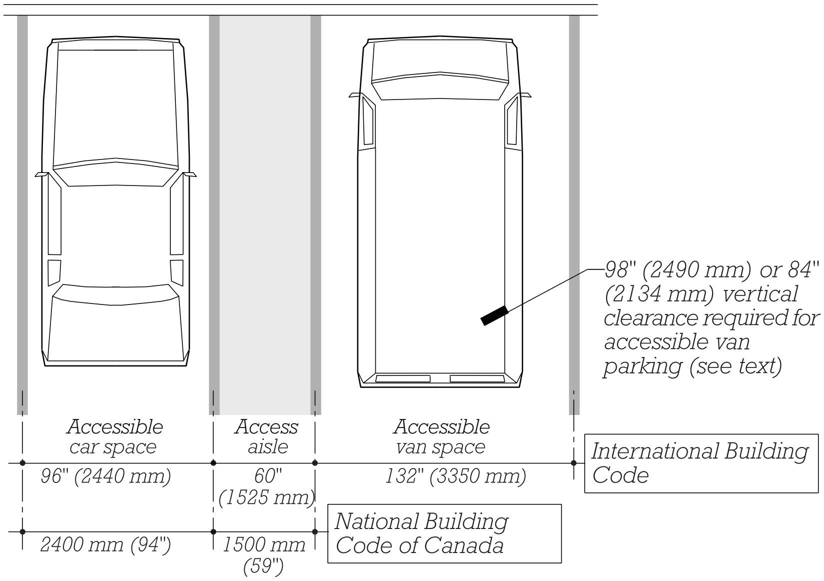
## INTERNATIONAL BUILDING CODE

The International Building Code requires accessible parking wherever surface or structured parking facilities serve accessible buildings. This includes most building types except detached one- and two-family residences (see pages 281–285 for more information). The table on this page lists the number of accessible spaces required for parking, depending on the building type served.

Where accessible parking spaces are required, one of every six spaces must be an accessible van space. In other words, where 1 to 6 accessible spaces are required, at least 1 must be accessible for vans; where 7 to 12 accessible spaces are required, at least 2 must be accessible for vans; and so on.

Accessible parking spaces must be located along the shortest accessible route to the building being served. Where there are multiple accessible entrances to a building, accessible parking spaces must be similarly dispersed. However, due to the special vertical clearance requirements of accessible van spaces, these may always be located solely on one level of a multilevel parking facility. Where accessible parking occurs on ramped tiers with slopes greater than 1:20 (5%), accessible routes must meet the requirements of accessible ramps.

Accessible car spaces must be at least 96 in. (2440 mm) wide, and accessible van spaces must be at least 132 in. (3350 mm) wide. Accessible van spaces, and the parking facility aisles and lanes connecting these spaces to public roadways, must provide a minimum vertical clearance of 98 in. (2490 mm). Or, where such van spaces are located in private garages serving R-2 or R-3 Residential, Multifamily or Miscellaneous Occupancies, the required minimum vertical clearance is 84 in. (2134 mm).



**DIMENSIONS FOR ACCESSIBLE PARKING IN THE INTERNATIONAL BUILDING CODE AND THE NATIONAL BUILDING CODE OF CANADA**

| Type of Use Served by Parking | Number of Accessible Parking Spaces Required by the International Building Code |
|---|---|
| Hospital outpatient facilities | 10% of visitor and patient parking |
| Rehabilitation and physical therapy facilities | 20% of visitor and patient parking |
| Occupancy Group R-2 Multifamily Residential and Group R-3 One- and Two-Family Residential buildings, where required to provide Type A or Type B accessible units | 2% of all parking, but not less than 1 accessible car space and 1 accessible van space |
| All other accessible buildings with: | |
| 1–25 total spaces | 1 accessible space |
| 26–50 total spaces | 2 accessible spaces |
| 51–75 total spaces | 3 accessible spaces |
| 76–100 total spaces | 4 accessible spaces |
| 101–150 total spaces | 5 accessible spaces |
| 151–200 total spaces | 6 accessible spaces |
| 201–500 total spaces | 6 accessible spaces, plus 1 per 100 (or fraction of 100) over 200 |
| 501–1000 total spaces | 2% of the total number of spaces to be accessible |
| 1001 or more spaces | 20 accessible spaces, plus 1 per 100 (or fraction of 100) over 1000 |

# ACCESSIBLE PARKING

All accessible parking spaces must have an access aisle, at least 60 in. (1525 mm) wide on at least one side, extending the full length of the space. One aisle can be shared by two accessible spaces, with one space on either side. Where accessible van parking spaces are angled, the access aisle must be on the passenger side of the van.

## NATIONAL BUILDING CODE OF CANADA

The National Building Code of Canada refers to local jurisdictions for barrier-free parking requirements. In the absence of such requirements, the code provides guidelines recommending that wherever more than 50 surface or structured parking spaces are provided, barrier-free spaces should be provided at the rate of one per every 100 spaces; see the table on this page.

| Type of Use Served by Parking | Number of Accessible Parking Spaces Recommended by the National Building Code of Canada |
|---|---|
| 1–50 total spaces | None |
| 51–100 total spaces | 1 accessible space |
| 101–200 total spaces | 2 accessible spaces |
| 201–300 total spaces | 3 accessible spaces |
| 301–400 total spaces | 4 accessible spaces |
| 401–500 spaces | 5 accessible spaces |
| 501 more total spaces | 1 accessible space for every 100 total spaces (or fraction of 100 spaces) |

Barrier-free parking spaces must be located close to a barrier-free entrance to the building they serve. Long paths of travel should be avoided. Where accessible parking occurs on ramped tiers with slopes greater than 1:20 (5%), barrier-free routes must meet all the requirements of barrier-free ramps (see pages 285–286 for more information on barrier-free routes).

Barrier-free spaces must be not less than 2400 mm (7'-1") wide and must be provided with an access aisle not less than 1500 mm (4'-11") wide on at least one side. One aisle can be shared by two barrier-free spaces, with one space on either side.

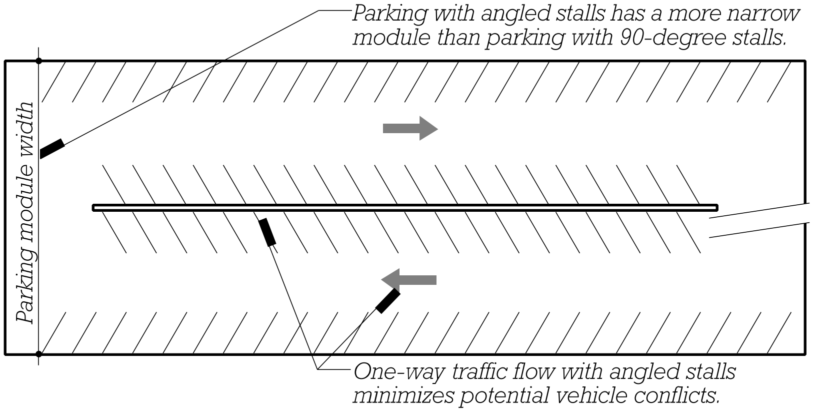
# 2

# CONFIGURING PARKING FACILITIES

*This chapter will aid you in the selection of a circulation scheme for your parking facility, provide guidance in the design of other aspects of the facility, and, in the case of structured parking, offer recommendations for the choice of a structural system.*

## ENTRANCES AND EXITS

Parking facility entrances and exits should be located away from street intersections, especially busy ones. Entrances, suitably distant from intersections, may be located on streets with high volumes of traffic inbound to the facility, making them easy for drivers to find and access. Or, in congested areas, entrances may be located on secondary streets to minimize interference with traffic on more heavily traveled thoroughfares. Entrances should provide one lane for every 300 to 500 stalls of parking. Entrance lanes should be long enough to allow queuing of several vehicles ahead of control points or turns into parking aisles. In structured parking facilities on sloped sites, entrances should be located strategically to minimize ramping within the facility. For example, for below-grade parking, it is advantageous to locate entrances close to the low end of the site. Where entrances and exits are separate, exits may be located where they discharge onto low-traffic-volume secondary streets, helping to minimize backups within the facility or disruption of traffic on main thoroughfares during times of heavy use.



**PARKING AISLE WITH ONE-WAY TRAFFIC FLOW AND ANGLED STALLS**

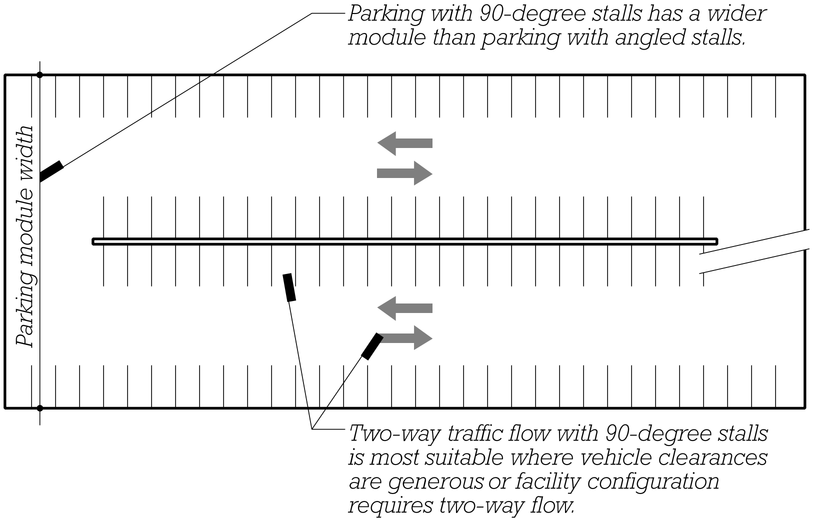
## PARKING AISLES AND STALLS

Within parking facilities, the designer has a choice of one-way or two-way traffic flow. One-way traffic flow minimizes opportunities for vehicle conflicts or collisions and reduces opportunities for congestion in heavily used facilities. One-way traffic flow is especially advantageous for structured parking facilities where driver site distances tend to be limited and parking dimensions are constrained. With one-way traffic flow, parking stalls should be angled. Stalls angled 75 degrees to the flow of traffic result in the highest efficiency, that is, the least area required per stall. Stalls angled at 60 degrees, though less efficient, may provide more comfortable vehicle entry and exit. Stalls angled at 45 degrees are the least efficient but also result in a *parking module* of the least width, that is, in the least combined width of drive aisle and stalls on either side. Intermediate angles may also be used, but stalls should never be angled at less than 45 degrees or more than 75 degrees.

# PARKING CIRCULATION BASICS

Two-way traffic flow is most suitable for facilities with generous vehicle clearances, for surface parking with multiple points of access where enforcing one-way flow is impractical, or where the configuration of structured parking requires two-way circulation. Where two-way traffic flow is provided, 90-degree parking stalls are preferred to allow the greatest flexibility in entering and exiting stalls from either direction. However, where a narrower parking module is required, angled stalls also may be used with stalls on opposite sides of aisles angled for flow in opposite directions. When comparing the space efficiency of 90-degree and angled stalls, two-way aisles with 90-degree stalls are typically about as efficient as one-way aisles with 75-degree stalls, as the greater compactness of the 90-degree stalls themselves is offset by the wider aisles required for two-way traffic circulation.

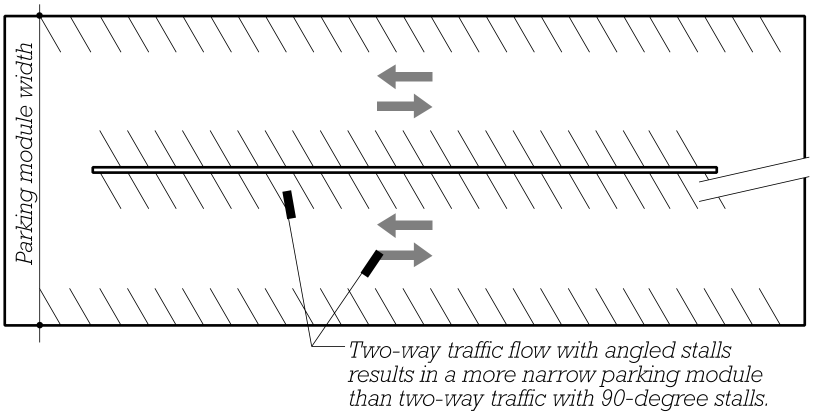
Circulation within a facility should be designed so that entering the facility, locating a stall, entering and exiting the stall, and leaving the facility require the fewest possible distinct vehicle maneuvers, such as turns or reversals in direction. Dead-end aisles should be avoided. The arrangements of stalls and aisles should be as consistent as possible from one section or tier of a facility to the next. There should be a logical, continuous route through the facility.



*Parking with 90-degree stalls has a wider module than parking with angled stalls.*

*Two-way traffic flow with 90-degree stalls is most suitable where vehicle clearances are generous or facility configuration requires two-way flow.*

**PARKING AISLE WITH TWO-WAY TRAFFIC FLOW AND 90-DEGREE STALLS**

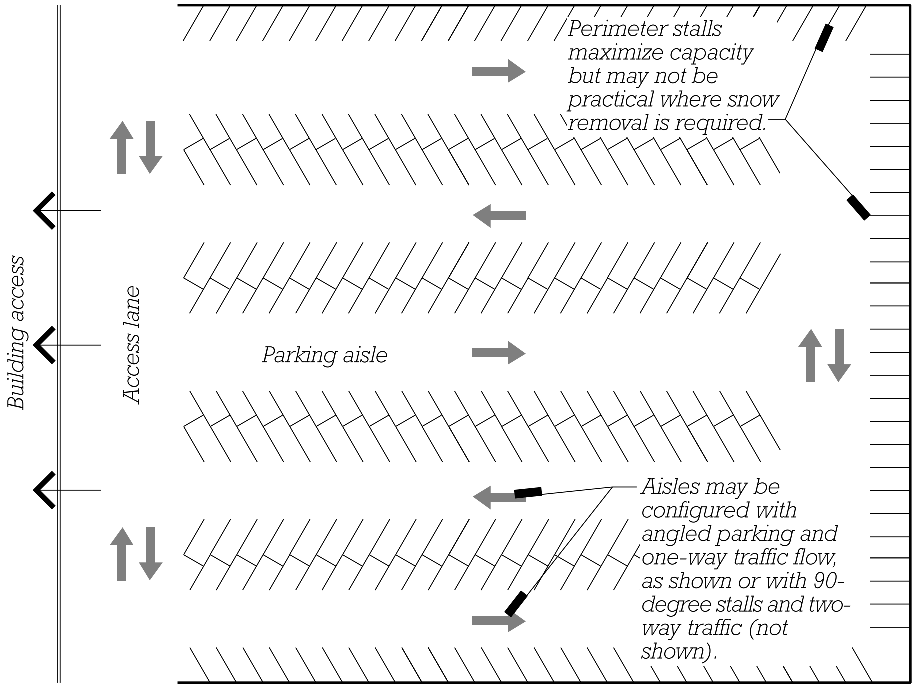


*Two-way traffic flow with angled stalls results in a more narrow parking module than two-way traffic with 90-degree stalls.*

**PARKING AISLE WITH TWO-WAY TRAFFIC FLOW AND ANGLED STALLS**

## SURFACE PARKING CIRCULATION

In its most common arrangement, surface parking is configured with an access lane located directly in front of the buildings served by the parking and with parking aisles aligned at right angles to the access lane. This arrangement permits passenger pickup and drop-off close to building entrances and allows pedestrian circulation between stalls and building entrances to occur within vehicle aisles. With long, narrow sites, stall efficiency may dictate that aisles be parallel to the longer dimension of the site. In this case, dedicated pedestrian pathways crossing rows of parking stalls may be required. Providing perimeter stalls, as illustrated in the accompanying diagram, increases stall efficiency but may interfere with snow removal in cold-climate regions. For the sizing of surface parking facilities, see pages 352–353.



*Perimeter stalls maximize capacity but may not be practical where snow removal is required.*

*Aisles may be configured with angled parking and one-way traffic flow, as shown or with 90-degree stalls and two-way traffic (not shown).*

**EXAMPLE SURFACE PARKING CIRCULATION PLAN**

## LANDSCAPING

Where the priority is to maximize parking capacity, landscaping with trees and shrubs is customarily confined to areas unusable for parking, such as ends of stall rows, inaccessible corners, and so on. Alternatively, greater extents of landscaping may be incorporated into a facility to meet requirements set by local design ordinances, to enhance the facility's comfort and appearance, or to mitigate its ecological impact. (In such cases, the number of available parking spaces will be reduced from the quantities indicated in the sizing guidelines provided in this chapter.) Where provided, landscaping must not interfere with sight lines. Plants that produce foliage within the range of 3 to 8 ft (0.9 to 2.4 m) above the ground should be avoided. Plants should also be kept comfortably away from vehicles to prevent damage to vehicle finishes and to avoid interference with users entering and exiting cars.

## SURFACE PARKING AND SUSTAINABILITY

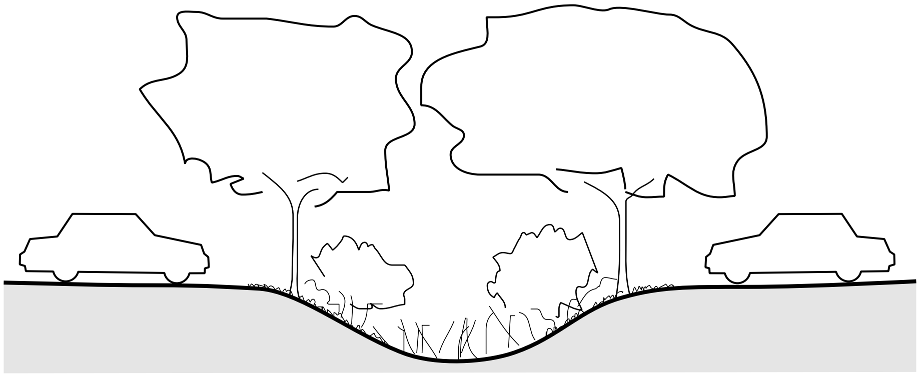
Surface parking consumes open land, reduces the quality of water in streams and lakes, and degrades the environment. Consider the following guidelines for minimizing these detrimental effects and designing greener, more sustainable surface parking.

**Reduce the Number of Parking Stalls:** Reducing the number of parking stalls reduces the area consumed by parking. Where land-use regulations set requirements for parking capacity, design to the minimum permitted. Where capacity is established through analysis of demand, design to projected average demand rather than peak demand or work with neighboring facilities to share parking where peak use times differ (e.g., day and evening uses or weekday and weekend uses).

**Reduce the Impervious Area:** Reducing the impervious (paved) area reduces the volume and intensity of stormwater runoff, helping to protect natural water features. Design narrower parking stalls and less generous aisles and lanes; in other words, consider a lower level of service for the facility. Lay out stalls and circulation for maximum efficiency. Use pervious paving materials (ones that permit surface stormwater to pass through the paving to the ground beneath) for overflow parking areas. Consider structured parking as an alternative to surface parking.

**Increase Planting:** Plants and trees reduce stormwater runoff. They hold water in their leaves and on their branches and stems. Plant roots increase the permeability of soil and its capacity to absorb water. Plantings, especially canopy trees, reduce heat island effects. Planted areas also create wildlife habitat and a more aesthetically interesting environment.

**Provide Natural Stormwater Retention:** Stormwater directed into shallow landscaped swales can infiltrate back into the soil or be discharged from the site at a more controlled rate. Such bioretention areas also aid the removal of pollutants in stormwater runoff and can reduce the need for more expensive, traditional stormwater management facilities.



BIORETENTION SWALE

**Minimize the Extent of Heat-Absorbing Surfaces:** Reducing the area of heat-absorbing paving lowers the air and surface temperatures of a parking facility, thereby improving user comfort, reducing health risks, lowering the temperature of stormwater leaving the site, and even lessening the energy consumption of nearby buildings. By using shading, lighter-colored or pervious paving, and covered parking to reduce the absorptive area by 50% or more, significant improvements in heat island effects can be achieved.

**Avoid Development of Ecologically Valuable Land:** Do not develop parking on prime farmland, in floodplains, on land providing habitat for endangered species, close to wetlands or productive bodies of water, or on land previously used as public parkland.

## STRUCTURED PARKING CIRCULATION

This chapter provides design guidelines for four configurations of vertical circulation in structured parking: single-threaded helix, double-threaded helix, split level, and multi-bay. These configurations are suitable for the preliminary design of efficient parking solutions meeting a broad range of requirements for facilities varying in size, use characteristics, and site constraints.

### Single-Threaded Helix

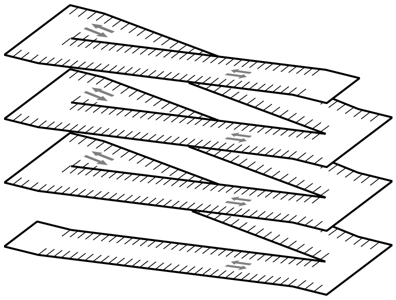
The *single-threaded helix* consists of a single continuously spiraling ramp, a configuration that is intuitively easy for users to navigate even when they are unfamiliar with the facility. An important characteristic of the single-threaded helix is that, being a single spiral, it cannot form a complete loop. Users leaving the facility must traverse in the opposite direction the same path used to arrive at their parking stall. Consequently, in their simplest form, single-threaded helix structures must be designed for two-way traffic flow. For the sizing of single-threaded helix structures, see pages 354–355.

### Double-Threaded Helix

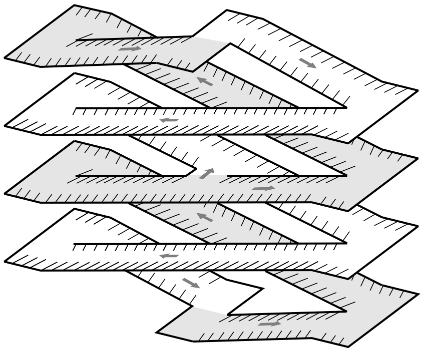
In a *double-threaded helix* configuration, two spiral ramps are intertwined so that a continuous loop is formed. Users traveling through such a facility can return to their original point of entry without ever retracing their path. A double-threaded helix structure can therefore be designed for one-way traffic flow, a configuration that minimizes congestion and conflicts between vehicles. This advantage is particularly important in facilities accessed by large numbers of users in relatively short time frames, where high peak vehicle flows create the greatest potential for traffic conflicts. In addition, users searching an entire facility for an available stall will have to pass each stall only once, since at the end of their search they will arrive back at the facility's entry. This is not the case in a single-threaded helix, where once users have searched all of the stalls, they arrive at the end of the spiral and must then retrace their path past the same stalls a second time in order to return to the place where they started. Double-threaded helix structures also allow for crossover aisles between adjacent ramps, providing shortcuts to facility exits. However, the double-helix structure is also a less intuitive configuration and one that may be confusing to infrequent users. For the sizing of double-threaded helix parking structures, see pages 356–357.

### Split Level

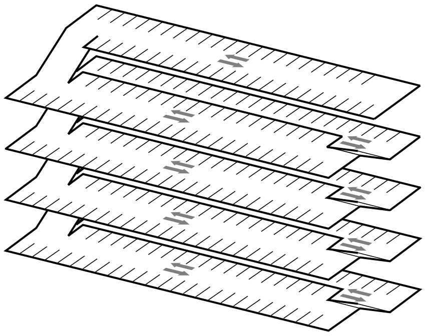
In a *split level* parking structure, level parking tiers are connected by *speed ramps* at either end. Adjacent tiers are staggered in a manner that creates a vehicle circulation pattern similar to that of a single helix; that is, a closed loop is not possible, and two-way traffic flow is required. In a split level structure, parking areas themselves are level, a benefit for user comfort and a feature that is particularly advantageous on constrained sites where bay lengths are short. As the length of the parking bay decreases in a single- or double-helix structure, ramps become more steeply sloped and increasingly uncomfortable for users. This is not the case for the split level structure, where parking tiers remain level regardless of length. Split level structures also conserve height (or depth in the case of below-grade structures) in comparison to ramped helix structures.



**SINGLE-THREADED HELIX CIRCULATION**



**DOUBLE-THREADED HELIX CIRCULATION**

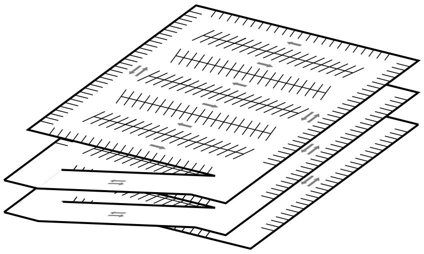


**SPLIT LEVEL CIRCULATION**

For example, a three-bay split level structure rises only as much as required for two ramps, since the first level is entirely at grade. In comparison, a three-bay single-threaded helix of similar extent and capacity must rise the combined height of three ramps. For the sizing of split level parking structures, see pages 358–359.

### Multi-Bay

*Multi-bay* facilities consist of relatively large-area parking tiers without slope connected by internal ramped parking or external *express ramps*. Facilities of this type offer advantages of high capacity, high user comfort, and the capability to manage high peak flows. For the sizing of multi-bay parking structures, see pages 360–361.



MULTI-BAY CIRCULATION

### Other Configurations

Variations on the circulation systems described above are also possible, though beyond the scope of this book to treat in detail. However, the overall capacity of such structures will not deviate significantly from the capacities derived from the charts in this text when considered on a proportional basis. In other words, for the purposes of preliminary design, an efficiently designed facility twice as wide as one designed using the charts in this book may be assumed to accommodate approximately twice as many vehicles, and so on. Where more detailed information on such configurations is needed, consult the references listed in this book's bibliography.

## STRUCTURED PARKING FACILITY DESIGN

The parking facility sizing information provided on pages 351 and 354–361 can be used to quickly determine the length, width, and height of a structure sufficient to provide parking for a specified number of vehicles. The dimensions provided by the charts account only for the parking system itself, that is, the ramps and aisles that vehicles use to circulate within the facility and the stalls in which they park. As explained in the text accompanying the charts, in some cases allowance is also made for the placement of structural columns or bearing walls. However, these charts do not account for other features such as stair towers, elevator shafts and lobbies, spaces for mechanical and electrical systems, and other possibly necessary items. In order to complete the preliminary design of a structured parking facility, the following requirements should also be considered, and the necessary spaces and elements incorporated into the design as appropriate to your project's requirements.

### Building Code Requirements

The maximum allowable height and area that are permitted for structured parking garages vary in each building code, depending on Construction Type, Occupancy classification, types of vehicles

| GIVE SPECIAL CONSIDERATION TO THE SYSTEMS INDICATED IF YOUR STRUCTURED PARKING FACILITY: | Single-Threaded Helix (Pages 354–355) | Double-Threaded Helix (Pages 356–357) | Split Level (Pages 358–359) | Multi-bay (Pages 360–361) |
|---|---|---|---|---|
| Is planned primarily for infrequent visitors unfamiliar with the facility | ● |  | ● | ● |
| Will be used primarily by regular users familiar with the facility |  | ● |  | ● |
| Is being constructed on a small, highly constrained site |  |  | ● |  |
| Will have high peak volume use |  | ● |  | ● |
| Is intended for large-capacity, high-volume parking |  |  |  | ● |

stored, whether the garage is open or enclosed, and other variables. For height and area limits for parking garages constructed under the International Building Code, see pages 436–439; for garages constructed under the National Building Code of Canada, see pages 468–471. If you do not know what building code applies to your project, see page 5.

## Exterior Walls

The parking facility sizing charts provide the length and width of the facility measured to the inside of the exterior walls of the structure. To arrive at overall dimensions, the thickness of exterior walls must be added to these figures. For preliminary design purposes, thicknesses ranging from 6 to 12 in. (150 to 300 mm) may be assumed. Or, once you have selected a structural system for your facility, information on specific wall systems can be found on the following pages:

- Wood stud walls: pages 58–59
- Brick masonry walls: pages 82–83
- Concrete masonry walls: pages 88–89
- Steel stud walls: pages 92–93
- Sitecast concrete walls: pages 110–111
- Precast concrete wall panels: pages 128–129

## Ventilation

Open parking structures must meet building code requirements for the extent of openings in exterior walls to ensure effective natural ventilation of the facility. If you do not already know which model building code applies to your project, see page 5.

In the International Building Code, each tier of an open parking structure must have exterior wall openings on at least two sides. These openings must be uniformly distributed, and their combined area may not be less than 20% of that tier's total wall area (as viewed from the interior). In addition, where exterior openings are not located on opposite sides of the structure, their aggregate length may not be less than 40% of the total length of the perimeter of the tier. Interior walls must also contain uniformly distributed openings constituting not less than 20% of each wall's area. A minimum separation is required from any exterior face of the garage with openings, measured from the exterior face to the center of a public street or boundary of an adjacent private property. This distance varies from 5 to 30 ft (1.5 to 9.1 m), depending on the extent of wall openings and whether the building is sprinklered. For preliminary design of garages with minimum wall opening area, assume a minimum distance of 5 ft (1.5 m) for sprinklered buildings and 15 ft (4.6 m) for unsprinklered buildings. The parking of trucks, buses, or other large vehicles, the dispensing of fuel, and the repair of vehicles are all prohibited in open parking garages under this code.

The National Building Code of Canada requires each tier of an open parking garage to have exterior wall openings with an area totaling not less than 25% of that tier's total wall area (as viewed from the interior). These openings must be arranged to ensure cross ventilation for the entire tier. A minimum distance of 3 m (9.8 ft) is required from any exterior building face with openings to the center of a public street or boundary of an adjacent private property.

Enclosed garages, which rely on mechanical ventilation to remove hazardous gasses and vapors, must include spaces for air handling equipment and ductwork. Air intakes for the ventilation system must be located safely away from sources of potentially contaminated air (above the uppermost tier or roof level, for example), and exhausts must not discharge toward exterior occupied areas or walkways. In order to minimize ceiling height conflicts, main supply ducts should be routed vertically through the structure and located such that the size and extent of horizontal branch ducts can be minimized. Required ventilation rates for enclosed parking garages are relatively high compared to those of conventionally occupied buildings to ensure adequate air handling capacity and the prevention of toxic gas accumulations. In order to reduce the high costs of continuously moving large quantities of air, many facilities rely on a system of carbon monoxide detectors to control ventilation rates, running the system at its highest capacity only when dangerous gas concentrations rise above specified levels. Cashier booths, offices, and other continuously occupied employee or public-use spaces within the facility should have their own dedicated supplies of conditioned air. For more information, see pages 185–186 for the design of fan rooms and pages 212–213 for the sizing of air handling system components. When using the chart on page 213, read to the far right in the bands labeled for various building types.

## Pedestrian Circulation

Pedestrian circulation within a single tier or floor normally occurs along the same aisles used by vehicles to access stalls. However, where the potential for hazardous conflicts between vehicles and pedestrians may occur, dedicated walkways or other safety measures should be provided. Examples of such areas include the top and bottom of ramps (especially steep ones), points where pedestrian or driver vision is limited, facility entrances and exits, places where automatic gates control vehicle movement, and so on.

To aid in wayfinding and maximize personal safety, pedestrian pathways should to the greatest extent possible provide a direct line of sight from car stalls to a level's primary entrance/exit, stairway, or elevator. For the same reason, exit stairs, elevator lobbies, and other components of the circulation system should be designed to be as open and transparent as possible. For user comfort, pedestrian routes within a facility should not exceed 350 to 700 ft (100 to 200 m) in total length, although they may be as long as 1200 ft (370 m) in facilities designed to low level of service standards. Exits must also comply with building code egress requirements. Information on the minimum number of exits, remoteness of exits, maximum travel distance, and other such criteria can be found beginning on page 272.

Facilities with more than two levels should provide elevators for vertical circulation. Elevators should be located prominently and as close as possible to the building or facility being served by the parking. Parking serving retail and office facilities should provide one elevator for approximately every 250 to 450 stalls. Parking serving special-use facilities with high peak demand will require a greater number of elevators, and large-area parking serving facilities such as airports or hospitals will require fewer. When elevators are provided, at least one exit stairway should be located nearby to provide alternative vertical circulation when elevators are out of service or wait times are excessive. For more information on the configuration and sizing of elevator systems, see pages 201–203.

## OTHER REQUIREMENTS

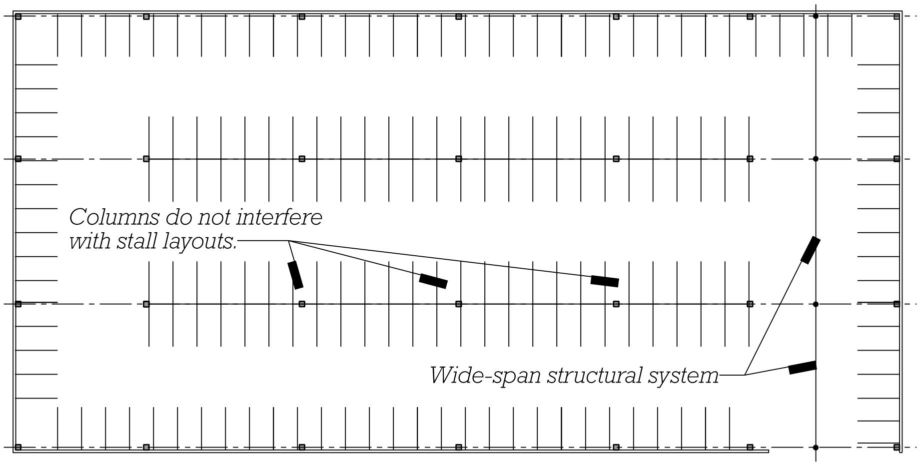
Other elements that should be considered in the design of a structured parking facility include:

- Structural systems: pages 347–348
- Accessible parking: pages 334–335
- Sprinkler systems: pages 189, 206
- Electrical closet: page 193
- Trash room for trash chute serving facilities above: page 188
- Staff offices or workrooms: page 189
- Transformer vault and switch gear vault for primary electrical power service for adjacent facilities: page 182
- Storage rooms
- Bicycle parking

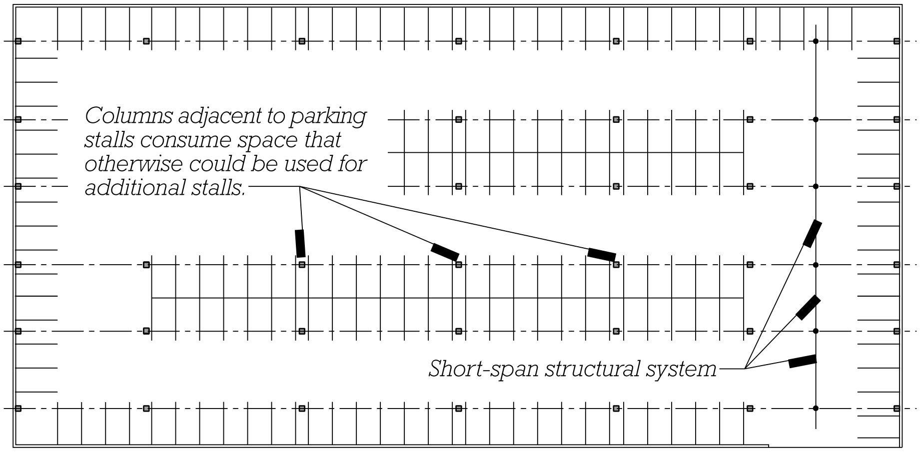
## COLUMN LOCATIONS AND STRUCTURAL SPAN

Wherever possible, structural systems should be selected that can span the full width of one parking module, that is, the combined width of one drive aisle and the stalls on either side. For typical parking layouts, this dimension varies from 50 to 65 ft (15 to 20 m). In this arrangement, columns do not intrude between stalls, stall widths are not compromised, and the greatest flexibility in current and future stall layouts is preserved.

Where shorter-span systems are used, columns must be located between parking stalls. In this arrangement, column spacing must be coordinated with stall spacing, and stalls adjacent to columns must be widened to provide clearance for vehicle movement and to allow space for opening doors. The result is less flexibility in the layout of parking stalls and a reduction in the total number of stalls. However, where such configurations are used, span requirements for the structural system may be as low as 15 to 25 ft (5 to 8 m).



**WIDE-SPAN STRUCTURE COLUMN LOCATIONS**



**SHORT-SPAN STRUCTURE COLUMN LOCATIONS**

## MIXED-USE BUILDINGS

In buildings where parking occurs above or below other uses, an important consideration is the coordination of structural elements between the different building parts. The building's primary vertical and lateral load-resisting systems must almost always be continuous from their highest point to the building's foundation. Other lines of load bearing must usually be vertically continuous to foundations as well, although in some circumstances and at significant cost, transfer structures may be used to shift the locations of such elements between different levels of a structure. Regardless of the approach taken, careful planning is required to develop structural configurations that are compatible with the requirements of the different parts of the building. In many cases, constraints on the placement of structural elements within the parking portion of the building may be the most restrictive. In such cases, the design of this portion of the building may have a strong influence on the entire structure, even to the point of dictating the column grid of the whole building. Due to the significant design and cost implications, the designer should thoroughly investigate the structural configuration of such mixed-use buildings at the earliest possible time. For more information on the configuration of structural systems, see pages 39–53, and for more information on the planning of service cores in buildings, see pages 190–192.

## SELECTION OF STRUCTURAL SYSTEMS

Structural systems for structured parking facilities should be capable of spanning the required distances for optimum column placement within the facility and, in the case of open parking structures, should be resistant to the effects of precipitation, road salt, and other exterior conditions. The most commonly used systems are precast concrete, sitecast concrete, and structural steel.

### Precast Concrete

Precast concrete is especially economical when used in repetitive configurations, such as those that are common in parking garage construction; it is resistant to the effects of exterior exposure, and it does not require added finishes to attain an acceptable appearance or to be protected from fire. The most common precast concrete spanning system used in structured parking facilities is the double tee. Although single tees are also capable of spanning the required distances, they are less economical and infrequently used. Where span requirements are more modest, hollow core planks may also be used. Guidelines for the design of precast concrete structures can be found on pages 125–135.

### Sitecast Concrete

Like precast concrete, sitecast concrete does not require added finishes to attain an acceptable appearance or for protection from fire. Where sitecast concrete will be exposed to the weather, systems with very thin slab sections, such as one-way joist or waffle slab, should be avoided due to their vulnerability to corrosion of reinforcing. A post and beam system with posttensioned one-way or two-way slabs may be a more suitable option in these conditions. Posttensioning, in which reinforcing is prestressed after it has been cast, has several advantages for the construction of sitecast concrete parking structures: It increases spans while minimizing structural depth, and for structures exposed to the weather, it improves the concrete's resistance to salts and corrosion. Guidelines for the design of sitecast concrete systems can be found on pages 107–123.

### Structural Steel

Structural steel is also used for the construction of structured parking facilities. Where it is exposed to the weather, it must be protected by high-performance paint-like coatings, galvanizing, or other protective coverings to prevent corrosion. Where required, protection from fire is most economically provided with spray-on insulating materials. In open parking structures, materials applied for protection from fire, unless naturally weather-resistant, must themselves also be coated or covered to be protected from the weather. Steel structural systems for structured parking facilities take the form of a steel post and beam with either concrete-topped steel floor decking or precast concrete solid or hollow core slabs. Guidelines for the design of steel structural systems can be found on pages 91–106.

## BUILDING CODE HEIGHT AND AREA LIMITS

Choice of a structural system for a structured parking facility is also limited by building code requirements. For parking facilities constructed to the requirements of the International Building Code, see pages 436–439, and for the National Building Code of Canada, pages 468–471. If you do not know what building code applies to your project, see page 5.

# 3

# SIZING PARKING FACILITIES

***This chapter will allow you to quickly determine the dimensions of a surface or structured parking facility to accommodate any required number of parking stalls.***

# GENERAL SIZING CRITERIA

The parking facility sizing charts on the following pages allow rapid determination of the overall dimensions of a parking configuration and the number of stalls accommodated. On this page, additional sizing information is provided for other aspects of the facility.

**Access Lanes:** For lanes without parking, a single lane should be 10 ft to 11 ft 6 in. (3000 to 3500 mm) wide, with an additional clearance to walls or other obstructions of not less than 6 in. to 2 ft (150 to 610 mm) on either side. A double lane should be 18 ft to 21 ft (5500 to 6400 mm) wide (for both drive lanes) plus the same side clearances as for a single lane. The outside radius of a turning lane should be 24 ft to 42 ft (7.3 to 12.8 m). Turning lanes are generally several feet wider than straight lanes.

**Vertical Clearance within Structured Facilities:** The International Building Code requires a minimum vertical clearance in parking structures of 7 ft 0 in. (2130 mm). The National Building Code of Canada requires a minimum of 2000 mm (6 ft 7 in.). Clearances of 7 ft 4 in. (2240 mm) or more improve user comfort, and this dimension may be increased to as much as 9 ft to 9 ft 8 in. (2740 to 2950 mm) in large facilities or those designed to high level of service conditions. Where accessible van parking spaces are provided, larger minimum clearances are required. See pages 334–335 for more information.

Prior to selection of a specific structural system, overall depth of the floor structure may be estimated at 2 ft 6 in. to 3 ft (750 to 900 mm), assuming wide-span structural systems. For more information on choosing structural systems for structured parking, see pages 347–348.

**Ramps:** Ramped parking areas (see Single-Threaded Helix, pages 354–355, or Double-Threaded Helix, pages 356–357) should not exceed slopes of 5% (1:20) wherever possible. More steeply sloped parking areas are less comfortable for users, make car entry and exit more difficult, and must be treated as ramps where accessible routes are required. Where an accessible route is not required, parking ramps sloped up to approximately 7% (1:14) may be considered for facilities designed to lower level of service standards. In high level of service facilities, ramped parking areas should be minimized or eliminated to the greatest extent possible. See pages 281–283 for information on accessible routes in the International Building Code or pages 285–286 for information on barrier-free routes in the National Building Code of Canada.

Speed ramps (see Split Level, pages 358–359) should normally not exceed slopes of 12.5% (1:8). Steeper slopes may be acceptable in locales where drivers are accustomed to steep drives. Express ramps (see Multi-Bay Parking, pages 360–361) should not exceed slopes ranging from 8% to 16% (1:12 to 1:6).

**Number of Tiers:** The number of complete 360-degree revolutions required to reach the farthest stalls in a facility should normally not exceed six to seven. For facilities designed to a high level of service, fewer revolutions should be used.

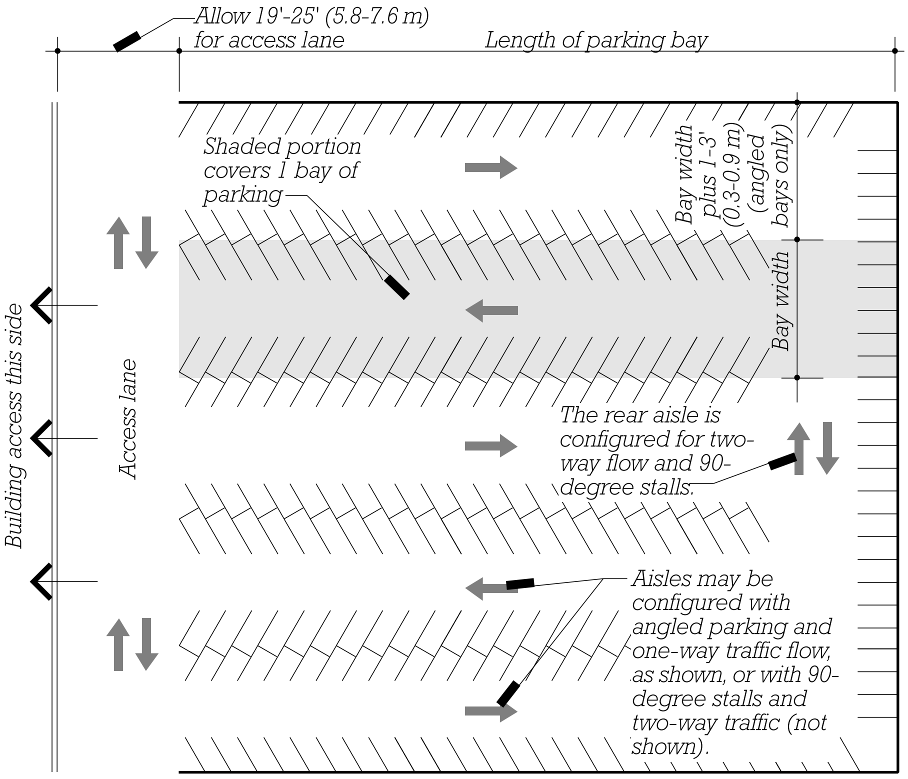
**Stall Sizes:** The parking facility sizing charts in this text are based on the assumption of uniform stall sizes throughout the facility. This approach is consistent with contemporary parking design guidelines that recommend against routinely providing a percentage of stalls sized for small cars only. This change from earlier practice reflects trends in the North American passenger vehicle population toward a larger percentage of wider vehicles and the lessening of the size difference between small and medium-sized cars. The effect of these trends has been to reduce the need for compact stalls and to blur the definition of what vehicles they are intended for, to the degree that their use has become increasingly problematic. For the preliminary layout of individual standard stalls, a size of 8 ft 6 in. × 18 ft (2590 × 5490 mm) may be used.

Where the use of compact stalls is considered, they should be limited to not more than 10% to 15% of the total spaces in a facility. They may also be used in particular locations within a facility where a standard-sized stall will not fit due to physical constraints. For preliminary design purposes, a compact stall size of 7 ft 6 in. × 15 ft (2290 × 4570 mm) may be used.

## PARKING BAY WIDTH

On the charts on the facing page, *Bay width* is the width of one typical double-loaded parking aisle. Bay widths differ for each level of service, and are indicated on the chart for Level of Service A and D conditions. Within any band, widths for intermediate levels of service may be interpolated by adding or subtracting approximately 1 ft (300 mm) for each single step in level.

When configured with angled stalls, parking bays located at either end of the parking area will be 1 to 3 ft (300 to 900 mm) wider than the inner bays. To determine the overall width of the parking area, multiply the width of one bay by the number of bays and then add 2 to 6 ft (600 to 1800 mm) for the wider bays at either end. When configured for 90-degree parking, no special allowance for end bays is required, and parking area width is determined simply by the width of one parking bay multiplied by the number of bays.



## EXAMPLE USE OF CHARTS

At least 500 stalls of surface parking are required as part of a suburban shopping center. The mall building is set back 450 ft from the main public roadway. Assuming high-turnover parking and users frequently accompanied by children or carrying bulky packages, Level of Service A conditions are proposed.

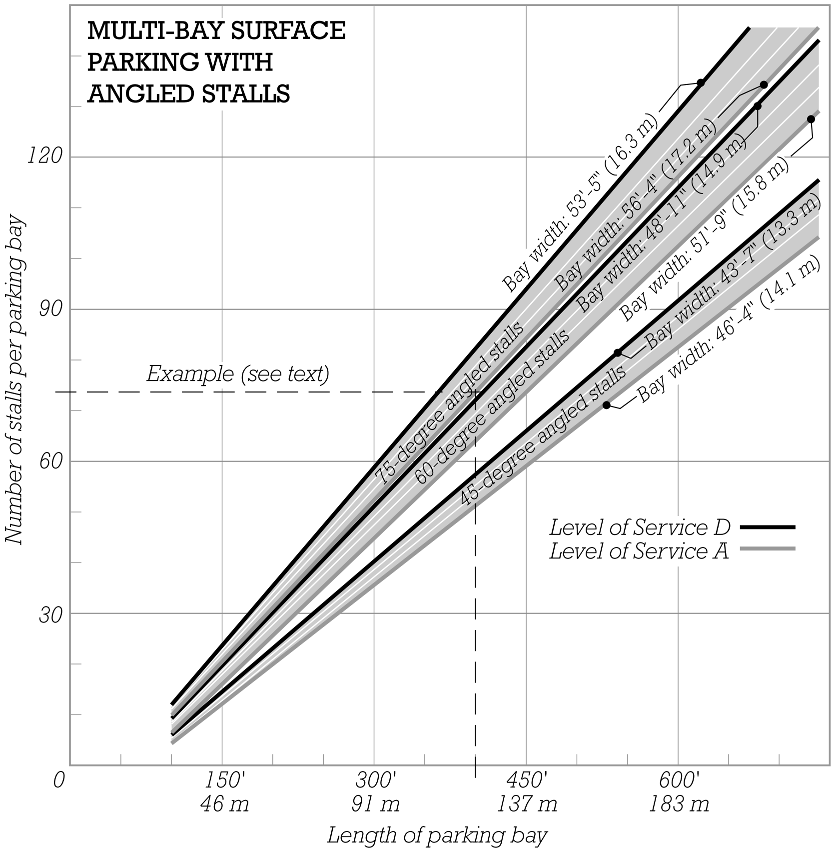
To provide the most convenient access to the mall building, parking aisles will be oriented perpendicular to the mall itself, as shown on the diagram on this page. To determine the space available for parking, 25 ft is subtracted from the building setback to account for landscape buffering, pedestrian walkways, and miscellaneous site features, and an additional 25 ft is subtracted to provide for the access lane running parallel to the mall entrance. The remaining available distance is 400 ft.

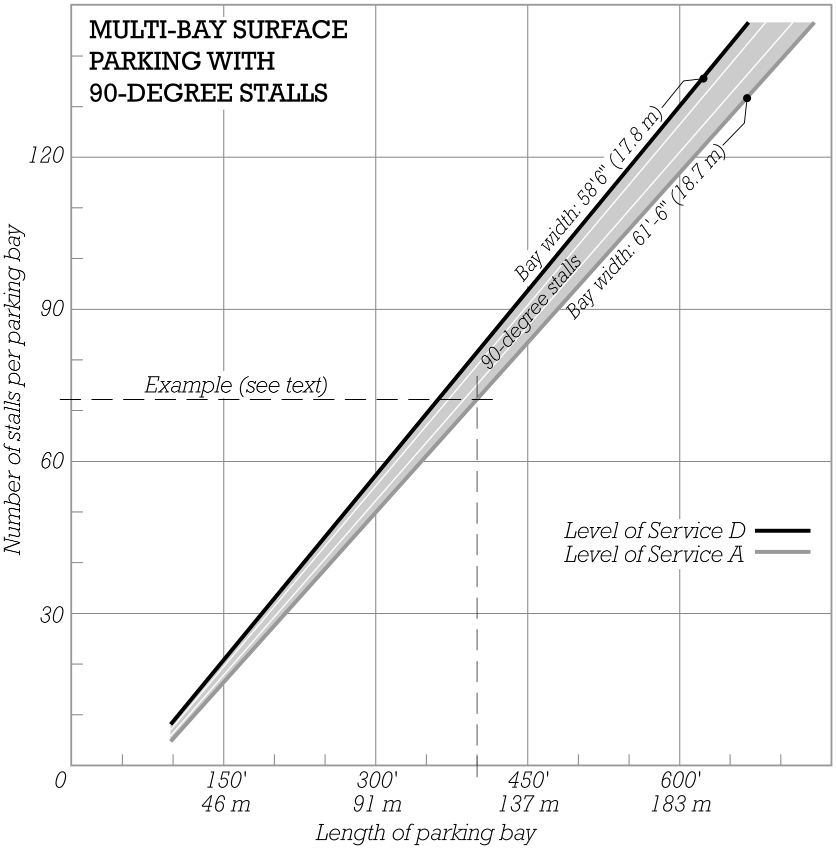
The first option considered is 75-degree angle parking with one-way traffic aisles. Reading from the upper chart on the facing page, we determine that a parking bay 400 ft long with Level of Service A conditions can accommodate 74 stalls in a bay 56 ft 4 in. wide. To accommodate the required number of stalls, seven bays are needed, providing 518 stalls (7 bays × 74 stalls per bay). To determine the overall width of the parking area, the width of one bay is multiplied by the number of bays, and an additional allowance of 3 ft is added to each side to account for wider end bays, as noted above. The result is 400 ft 3 in. (7 bays × 56 ft 4 in. per bay + 2 × 3 ft end bay allowance).

As a possible alternative, parking with 90-degree stalls and two-way traffic aisles is also considered. Reading from the lower chart on the facing page, we determine that a parking bay 400 ft long with Level of Service A conditions can accommodate 72 stalls in a bay 61 ft 6 in. wide. Again, seven bays of parking are required, providing 504 stalls total. In this case, since end bays do not need to be widened, the overall width of the parking area is the width of one bay multiplied by the number of bays, or 430 ft 6 in. (7 × 61 ft 6 in.).

We conclude that either option is a viable configuration. If minimizing the land area occupied by parking is the higher priority, the angled parking solution may be used. Or, if providing the greatest flexibility in vehicle circulation is desired, the 90-degree parking solution may be chosen.

# SIZING SURFACE PARKING





Use the two charts on this page to determine the length and width of a multi-bay surface parking facility as illustrated on the facing page. *Length of parking bay* is the length of one parking aisle and the adjacent perimeter aisle and stalls. *Number of stalls per parking bay* is the number of stalls within one bay (see the shaded area in the diagram).

The top chart is for parking aisles configured primarily with one-way aisles and angled stalls.

■ Read in one of the three indicated bands for parking configured within the one-way aisles as either 75-, 60-, or 45-degree angled stalls. Within each band, read along the bottom for Level of Service A conditions (most generously dimensioned) or along the top for Level of Service D (most constrained). Intermediate Levels of Service B and C are also represented by the thin white lines within each band. See page 333 for more information on selecting the appropriate level of service for your facility.

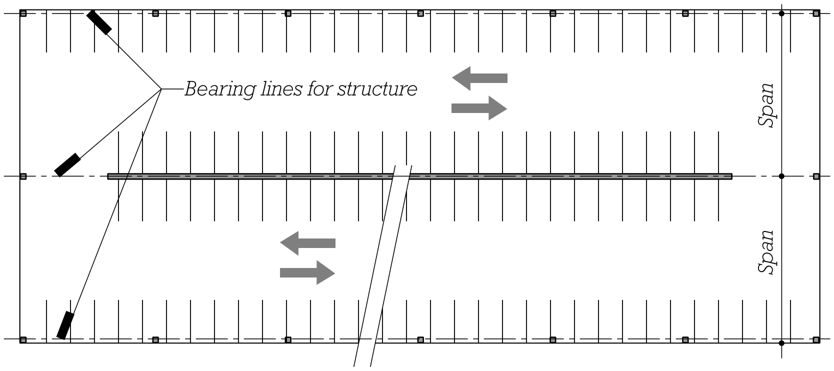
■ To determine the width of one parking bay, as well as the overall width of the parking facility, see the instructions for Parking Bay Width on the facing page.

The bottom chart is for aisles configured throughout for two-way traffic flow with 90-degree stalls.

■ Read along the bottom of the indicated band for Level of Service A conditions (most generously dimensioned) or along the top for Level of Service D conditions (most constrained). Intermediate Levels of Service B and C are also represented by the white lines within each band.

## LOCATION OF COLUMNS AND BEARING WALLS

The dimensions read from the chart on the facing page (as well as those on pages 357 and 359) include allowances for columns and bearing walls located along three lines of bearing, as indicated in the adjacent diagram. Columns located along the perimeter may intrude up to 2 ft (0.6 m) into the ends of parking stalls or into the turning lanes at the ends of the ramps. A 2-ft (0.6-m) allowance is also provided for columns or a wall located along the bearing line between the ramps on either side. In this configuration, a floor system capable of spanning one-half of the total width of the structure is required. Shorter-span systems should be avoided, since when columns fall between stalls, stalls must be widened and the number of stalls per bay must be reduced. See pages 347–348 for more information on selecting structural systems for parking structures.



## EXAMPLE USE OF CHART

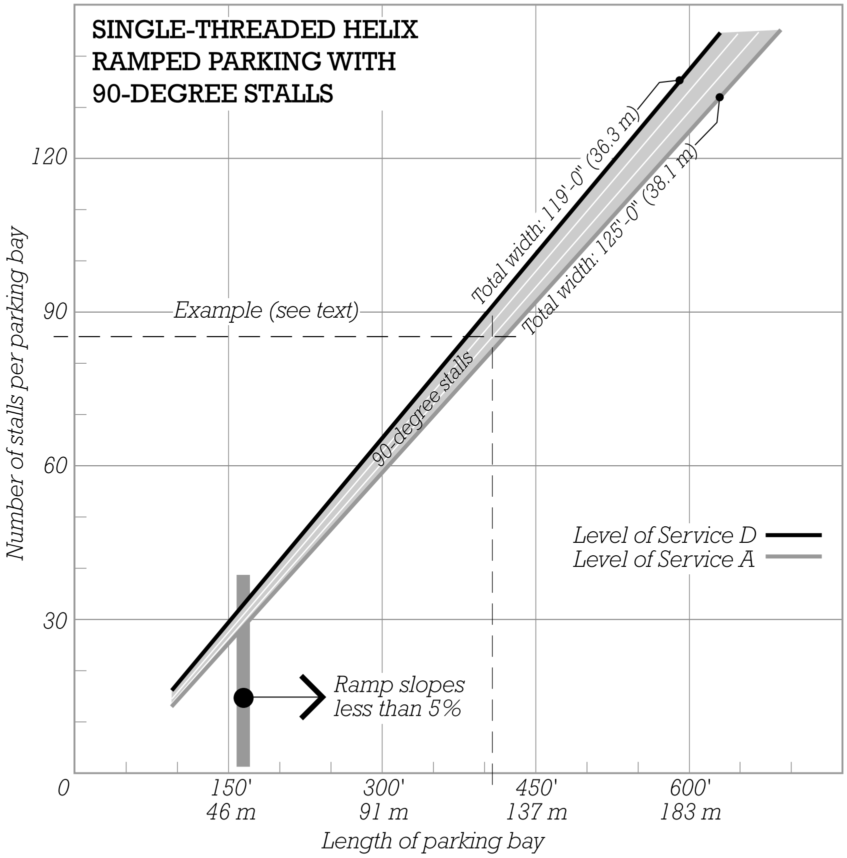
At least 500 stalls of structured parking are required for a small urban shopping complex. The site available for the parking structure is 420 ft long. Assuming mostly short-term parking and users unfamiliar with the facility, a single-threaded helix configuration is proposed, with two-way traffic, 90-degree parking stalls, and Level of Service B conditions.

To determine the maximum possible length of the parking bays within the structure, 5½ ft is subtracted from each end of the site to allow for site features and the thickness of exterior walls, resulting in a length of 410 ft. Referring to the chart on the facing page, we see that one such parking bay, sized for Level of Service B conditions, can accommodate 85 stalls. Six bays of parking will be required, providing 510 stalls total (six bays × 85 stalls per bay). Interpolating between the bay widths indicated for Levels of Service A and D, we determine that the width of the structure, excluding exterior walls, will be 123 ft.

To determine the height of the structure, we refer to the lower diagram on the facing page and note that each sloped bay of a single-threaded helix structure rises one-half of the structure's floor-to-floor height. Allowing 11 ft floor-to-floor, each bay will rise 5½ ft, and six bays of parking will have a total height of 33 ft (6 × 5.5 ft = 33 ft). Assuming that open-air parking is acceptable on the uppermost levels, no additional roof structure is proposed, and the height of the structure from its entrance to its highest parking level, excluding parapets, will be 33 ft. (For more information on floor-to-floor heights in structured parking, see page 351.)

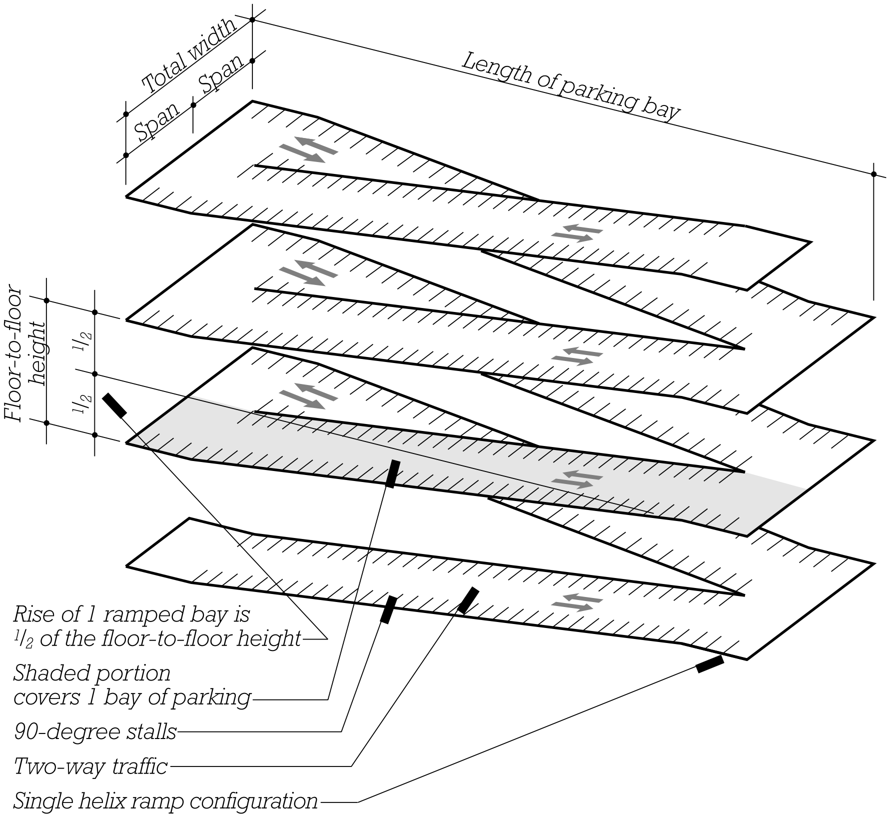
In order not to compromise stall widths, structural systems considered for this building should be capable of spanning one-half of the building's overall width, or approximately 60 to 65 ft. Now that the configuration of the parking system itself has been completed, the next steps in this design process will be the consideration of pedestrian circulation, building systems, and other elements. See pages 344–346 for more information on these subjects.

# SIZING SINGLE-THREADED HELIX PARKING STRUCTURES



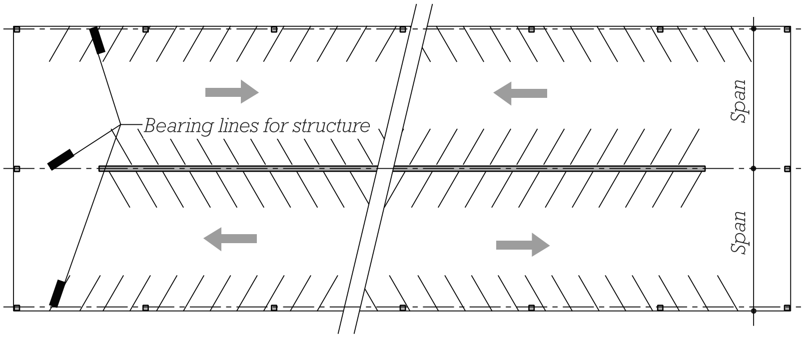
Use this chart to determine the length and width of a parking structure configured as a single-threaded helix ramp, with two-way traffic and 90-degree stalls. *Length of parking bay* is the dimension of the structure parallel to the ramps, excluding the thickness of exterior walls. *Number of stalls per parking bay* is the number of stalls within one parking bay (see the shaded area in the diagram below).

- ■ Read along the bottom of the indicated band for Level of Service A conditions (most generously dimensioned) or along the top for Level of Service D (most constrained). Intermediate Levels of Service B and C are also represented by the white lines within each band. See page 333 for more information on selecting the appropriate Level of Service condition for your facility.
- ■ *Total width*, which differs with each level of service condition, is the dimension of the structure perpendicular to the ramps, excluding the thickness of exterior walls. Total width is indicated on the chart for Level of Service A and D conditions. Within any band, widths for intermediate levels of service may be interpolated by adding or subtracting approximately 2 ft (0.6 m) for each single step in level.
- ■ To avoid parking ramps with uncomfortably steep slopes, read to the right of the vertical bar indicated for ramp slopes less than 5% (1:20).
- ■ Guidelines for incorporating pedestrian circulation, building systems, and other elements necessary to complete the design of a structured parking facility are provided on pages 344–346.



## LOCATION OF COLUMNS AND BEARING WALLS

The chart on the facing page includes allowances for columns and bearing walls for a structural system spanning one-half of the total width of the structure. This structural configuration is discussed in more detail on page 347.



## TOTAL WIDTH OF STRUCTURE

To determine the width of the structure, read *Total width* on the chart, which differs with each level of service condition. This dimension is the width of the structure perpendicular to the ramps, excluding the thickness of exterior walls. Figures are provided for Level of Service A and D conditions. Within any band, widths for intermediate levels of service may be interpolated by adding or subtracting 2 ft (0.6 m) for each single step in level.

## CROSSOVER AISLES

Figures provided on the chart on the facing page allow for crossover aisles at every other pair of ramps, as illustrated in the lower diagram. If crossovers are provided at every crossing, stall totals will be reduced.

## RAMP SLOPES

To avoid parking ramps with uncomfortably steep slopes, read only to the right of the vertical bar, as indicated for ramp slopes less than 5% (1:20).

## EXAMPLE USE OF CHART

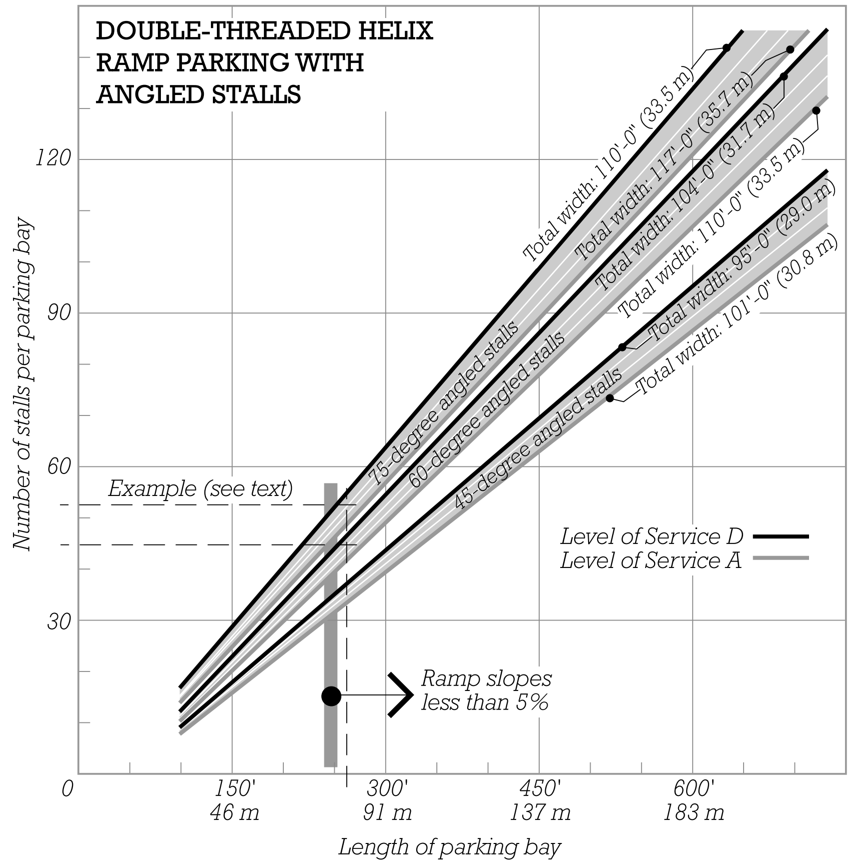
At least 255 stalls of structured parking are required as part of an urban office building complex. The site available for the parking structure is 265 ft long. Assuming mostly all-day parking and users who are familiar with the facility, a double-threaded helix configuration is proposed, with one-way traffic, 75-degree parking stalls, and Level of Service C conditions.

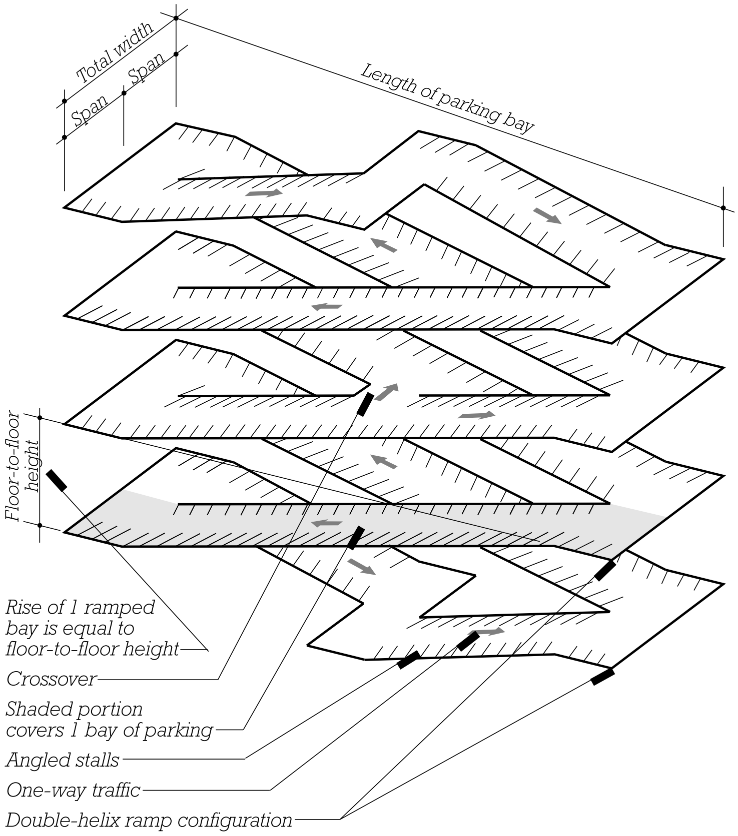
To determine the maximum possible length of the parking bays within the structure, 2 ft 6 in. is subtracted from each end of the site to allow for site features and the thickness of exterior walls, resulting in a length of 260 ft. Referring to the chart on the facing page, we see that one such parking bay with 75-degree angled parking and sized for Level of Service C conditions can provide 53 stalls. To provide the required 255 stalls, slightly more than five bays of parking are required. Referring to the diagram below the chart, we note that a double-helix structure must always be configured with an even number of parking bays (pairs of half-bays at the top and bottom, and pairs of full bays in between). In the proposed configuration, a four-bay structure can provide 220 stalls (four bays × 55 stalls per bay), an insufficient number, and a six-bay structure can provide 330 stalls (six bays × 55 stalls per bay), a number significantly in excess of that required. One option to arrive closer to the required number of stalls would be to reduce the structure's length. However, studying the chart, we note that parking bays less than approximately 250 ft in length will have ramps with slopes greater than 5% (1:20), an important threshold for user comfort and accessible routes. So, we reject this option. Another option is to adjust the angle of parking stalls to 60 degrees. Although somewhat less space-efficient, 60-degree angled stalls are also more comfortable for parkers. In this configuration, each parking bay can accommodate 45 stalls, and six bays can provide a total of 270 stalls (six bays × 45 stalls per bay), slightly more than the number required. To determine the width of the structure, with Level of Service C conditions, we interpolate between the figures provided for Levels A and D for 60-degree angled parking and obtain a width of 106 ft.

To determine the height of the structure, we refer to the lower diagram on the facing page and note that each pair of bays of a double-threaded helix structure rises the same distance as the structure's floor-to-floor height. Allowing 10 ft floor-to-floor, each parking bay will also rise that same distance, and three pairs of parking bays will have a total height of 30 ft (3 × 10 ft). Assuming that the top bays of parking should be protected from the weather, an additional 10 ft is added for the roof level, and the overall building height is calculated as 40 ft from its entrance level to the top of the roof. (For more information on floor-to-floor heights in structured parking, see page 351.)

In order not to compromise stall widths, structural systems considered for this building should be capable of spanning one-half of the building's overall width, or approximately 50 to 55 ft. Now that the configuration of the parking system itself has been completed, the next steps in this design process would be the consideration of pedestrian circulation, building systems, and other elements. See pages 344–346 for more information on these subjects.

# SIZING DOUBLE-THREADED HELIX PARKING STRUCTURES





Use this chart to determine the length and width of a parking structure configured as a double-threaded helix ramp, with one-way traffic and angled stalls. *Length of parking bay* is the dimension of the structure parallel to the ramps, excluding the thickness of exterior walls. *Number of stalls per parking bay* is the number of stalls within one parking bay (see the shaded area in the diagram below).

- Read in one of the three indicated bands for parking configured within the one-way aisles as either 75-, 60-, or 45-degree angled stalls. Within each band, read along the bottom for Level of Service A conditions (most generously dimensioned) or along the top for Level of Service D (most constrained). Intermediate Levels of Service B and C are also represented by the thin white lines within each band. See page 333 for more information on selecting the appropriate level of service condition for your facility.
- In determining the number of bays required, note that double-helix structures must always have an even number of parking bays.
- See the facing page for instructions on determining the overall width of the structure and further information on crossover aisles and ramp slopes.
- Guidelines for incorporating pedestrian circulation, building systems, and other elements necessary to complete the design of a structured parking facility are provided on pages 344–346.

## LOCATION OF COLUMNS AND BEARING WALLS

The chart on the facing page includes allowances for columns and bearing walls for a structural system spanning one-half of the total width of the structure. This plan configuration is discussed in more detail on page 347.

## OVERALL WIDTH OF STRUCTURE

To determine the width of the structure, read *Total width* on the chart, which differs with each level of service condition. This dimension is the width of the structure perpendicular to the ramps, excluding the thickness of exterior walls. Figures are provided for Level of Service A and D conditions. Within any band, widths for intermediate levels of service may be interpolated by adding or subtracting 2 ft (0.6 m) for each single step in level.

## SPEED RAMPS

The slope of the speed ramps in a split level parking structure varies with the elevation difference between adjacent tiers and, to a lesser extent, with aisle dimensions derived from the stall angle and level of service condition. For preliminary purposes, elevation differences of greater than 5 ft (1.5 m) between adjacent tiers should be avoided in order to avoid ramps with uncomfortably steep slopes of more than approximately 12.5% (1:8).

## EXAMPLE USE OF CHART

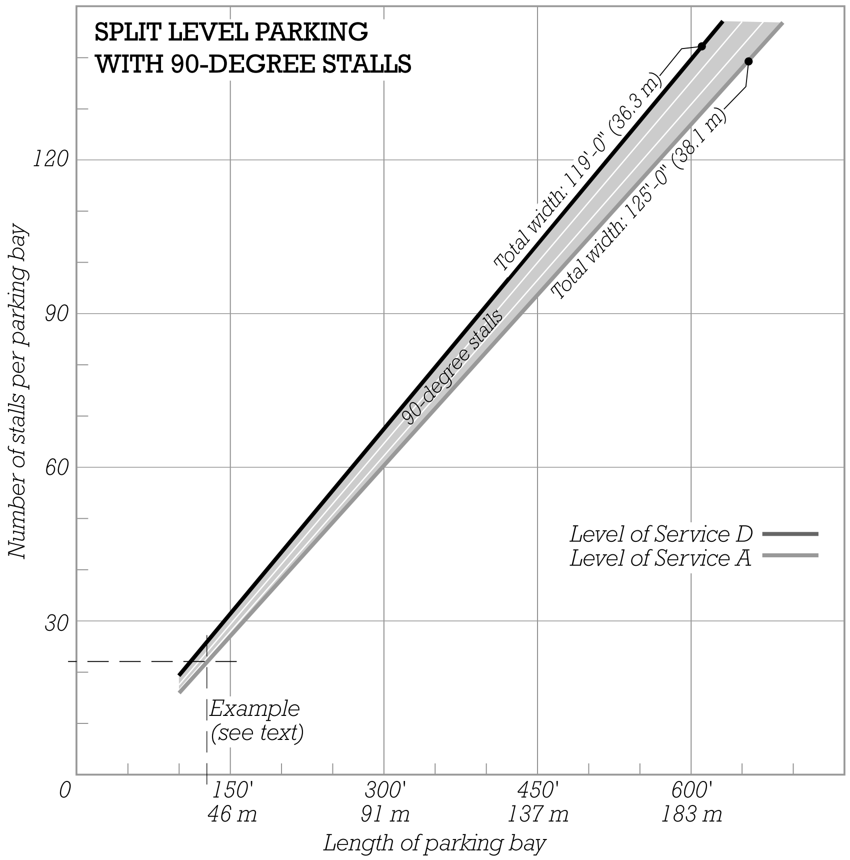
At least 55 stalls of Level of Service D structured parking are required beneath a condominium building in a dense urban setting. The building site is 130 ft long. Ramped single- and double-threaded helix structures have already been considered and rejected for this relatively small site due to the uncomfortably steep slopes that result within the stall areas.

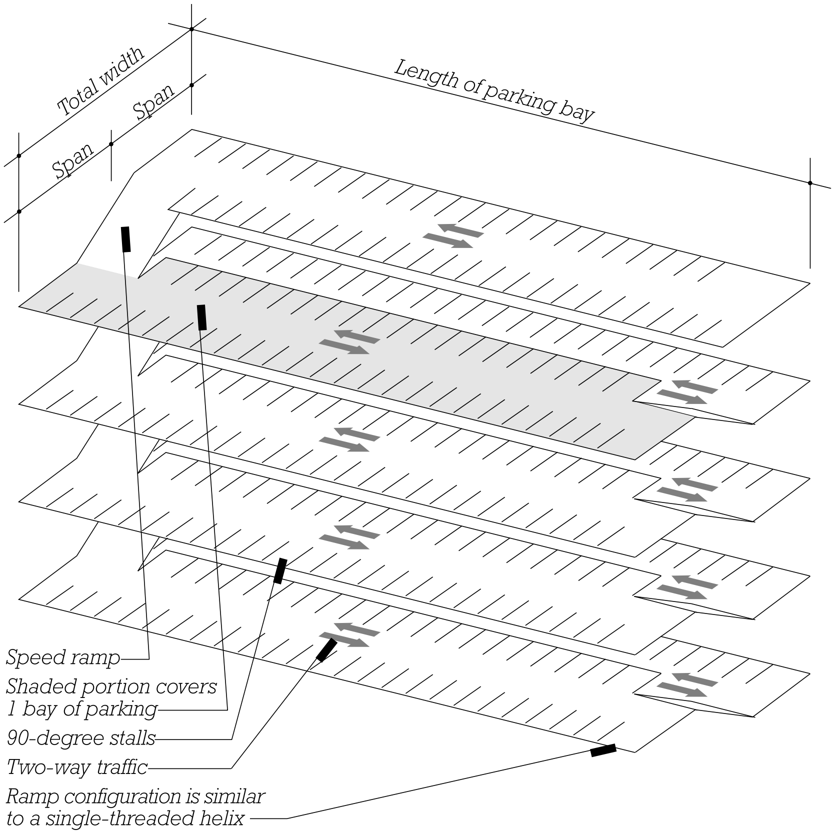
To determine the maximum possible length of the parking bays within the structure, 2 ft 6 in. is subtracted from each end of the site to allow for the thickness of foundation walls and related construction, resulting in a length of 125 ft. Referring to the chart on the facing page, we see that such a parking bay can provide 23 stalls with Level of Service D conditions. Three bays of parking will be required, capable of providing up to 69 stalls. In this case, 55 stalls will be provided and the excess area will be set aside for building service spaces. From the chart, we can also see that with Level of Service D conditions, the width of the structure within surrounding foundation walls must be at least 119 ft.

Referring to the lower diagram on the facing page, we see that a split level parking structure is similar to a single-threaded helix in that the elevation change from one tier to the next is one-half of the structure's floor-to-floor height. Allowing 10 ft floor-to-floor, each parking bay will descend 5 ft. However, unlike the single-threaded helix, in a split level structure the first bay of parking occurs entirely at the entrance level. In a three-bay structure, the lowest bay is only two tiers below the uppermost. Therefore, the lowest bay of parking will be only 10 ft (2 × 5 ft) below the entrance.

In order not to compromise stall widths, structural systems considered for this building should be capable of spanning one-half of the building's overall width, or approximately 60 ft. Now that the configuration of the parking system itself has been completed, the next steps in this design process would be the consideration of pedestrian circulation, building systems, and other elements. See pages 344–346 for more information on these subjects.

# SIZING SPLIT LEVEL PARKING STRUCTURES

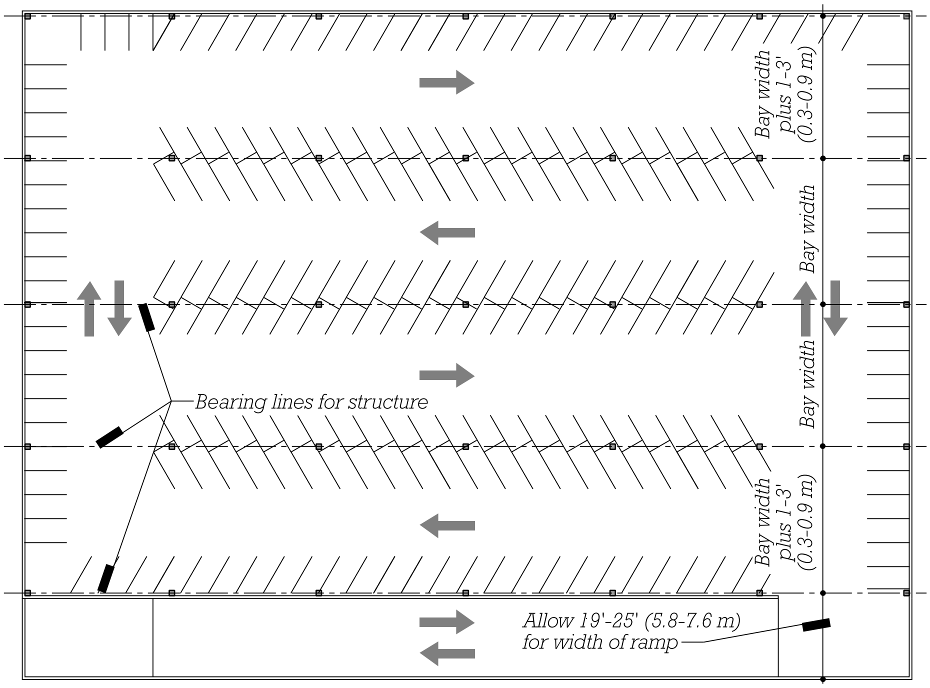




Use this chart to determine the length and width of a parking structure configured as split level parking, with two-way traffic and 90-degree stalls. *Length of parking bay* is the dimension of the structure parallel to the parking aisles, excluding the thickness of exterior walls. *Number of stalls per parking bay* is the number of stalls within one parking bay (see the shaded area in the diagram below).

- Read along the bottom of the indicated band for Level of Service A conditions (most generously dimensioned) or along the top for Level of Service D (most constrained). Intermediate Levels of Service B and C are also represented by the white lines within each band. See page 333 for more information on selecting the appropriate level of service condition for your facility.
- See the facing page for instructions on determining the overall width of the structure and further information on ramp slopes.
- Guidelines for incorporating pedestrian circulation, building systems, and other elements necessary to complete the design of a structured parking facility are provided on pages 344–346.

# SIZING MULTI-BAY PARKING STRUCTURES



## STRUCTURAL SYSTEMS

A structural system should be selected that is capable of spanning the full width of a single parking bay. Shorter-span systems should be avoided, since when columns fall between stalls, stalls must be widened and the number of stalls per bay must be reduced. See pages 347–348 for more information on selecting structural systems for parking structures.

## PARKING BAY WIDTH AND WIDTH OF STRUCTURE

On the chart on the facing page, *Bay width* is the width of one typical double-loaded parking aisle. Bay width differs with each level of service condition and is indicated on the chart for Level of Service A and D conditions. Within any band, widths for intermediate levels of service may be interpolated by adding or subtracting approximately 1 ft (0.3 m) for each single step in level. Parking bays located at either end of the parking area will be 1 to 3 ft (0.3 to 0.9 m) wider than inner bays. To determine the overall width of the parking area, multiply the width of one parking bay by the number of bays and then add 2 to 6 ft (0.6 to 1.8 m) for the wider bays at each end.

## EXAMPLE USE OF CHART

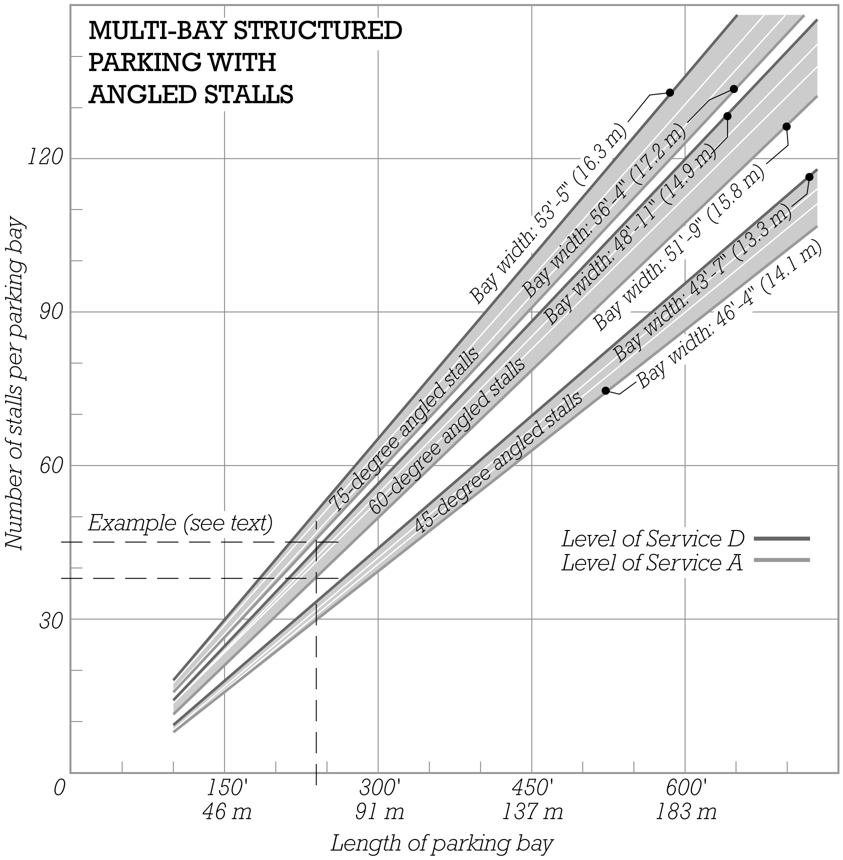
At least 950 stalls of parking are required for a regional airport facility. The building site is 260 ft in length in the direction parallel to the planned parking aisles within the facility and 490 ft wide in the perpendicular direction. Assuming mostly short-term parking and users unfamiliar with the facility, Level of Service A conditions with 60-degree angled parking are proposed.

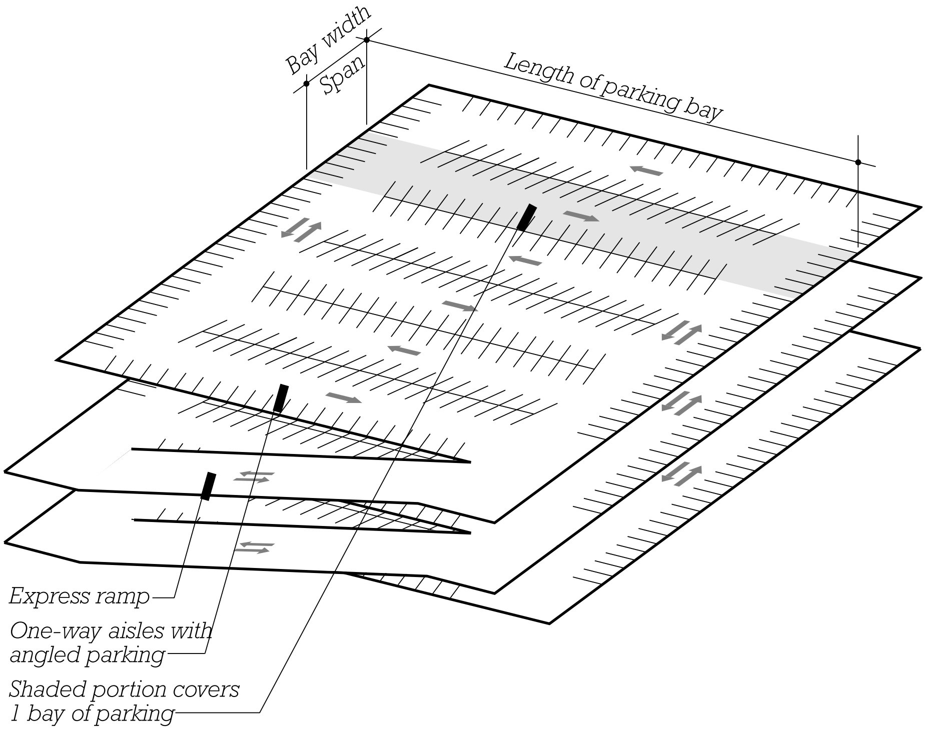
To establish the maximum possible length of the parking bays within the structure, 10 ft is subtracted from each end of the site to allow for site features and the thickness of exterior walls, resulting in a length of 240 ft. Referring to the chart on the facing page, we determine that such a parking bay with 60-degree angled stalls and Level of Service A conditions can provide 38 stalls in a bay 51 ft 9 in. wide.

To determine the width available for parking bays, we subtract from the width of the site 10 ft at each end for site conditions and exterior wall thickness, 25 ft at one end for the express ramp, 15 ft at the other end for various vertical circulation and building services, and 3 ft at each end for the wider parking bays required at the sides, as noted above. The resulting width is 424 ft. Eight parking bays with an overall width of 414 ft (8 × 51 ft 9 in. per bay) and a total of 304 stalls (8 × 38 stalls per bay) can fit within this dimension. As an alternative, we also try a configuration with 75-degree angle stalls. In this case, a bay 56 ft 4 in. wide can provide 45 stalls of parking. Only seven bays can fit within the space, but with a total of 315 stalls in an overall width of 394 ft 4 in. In this second configuration, we can accommodate 11 more stalls per parking level in a structure roughly 20 ft smaller in width. We select the second option.

Assuming 11 ft 6 in. floor-to-floor heights and open-air parking at the top level, the top of the structure, not including parapets, will be 34 ft 6 in. (3 × 11 ft 6 in.) above the entrance level. Now that the configuration of the parking system itself has been completed, the next steps in this design process will be the consideration of pedestrian circulation, building systems, and other elements. See pages 344–346 for more information on these subjects.

# SIZING MULTI-BAY PARKING STRUCTURES





Use this chart to determine the length and width of a large-area multi-bay parking structure configured with express ramps and a combination of one-way and two-way aisles, as shown in the diagram below. *Length of parking bay* is the dimension of the structure parallel to the parking aisles, excluding the thickness of exterior walls. *Number of stalls per parking bay* is the number of stalls within one bay (see the shaded area in the diagram).

■ Read in one of the three indicated bands for parking configured within the one-way aisles as either 75-, 60-, or 45-degree angled stalls. Within each band, read along the bottom for Level of Service A conditions (most generously dimensioned) or along the top for Level of Service D (most constrained). Intermediate Levels of Service B and C are also represented by the thin white lines within each band. See page 333 for more information on selecting the appropriate level of service condition for your facility.

■ Guidelines for incorporating pedestrian circulation, building systems, and other elements necessary to complete the design of a structured parking facility are provided on pages 344–346.

## SECTION

## 7

# DESIGNING WITH HEIGHT AND AREA LIMITATIONS

# 1

# HEIGHT AND AREA LIMITATIONS

***This chapter explains how building code height and area limitations, Construction Type definitions, and related concepts influence the size and form of your building.***

# HEIGHT AND AREA LIMITATIONS

The model codes place limitations on building heights and areas in relation to the type of construction employed and the nature of the activities taking place within the building. This is done in order to ensure a minimum standard of life and fire safety for the occupants of the building as well as for surrounding buildings. Height and area limitations, because they limit building size and dictate the types of construction from which the designer may choose, have the largest impact on building design of any building code provisions. It is not uncommon during early design for consideration of these limits to lead to significant changes in program requirements or building massing simply to enable the use of the most economical construction systems possible.

Though both model building codes approach limitations on building height and area with similar goals, the particulars of how these requirements are defined and the results achieved differ significantly between them. To the maximum extent possible, these differences have been minimized in the height and area tables provided in this text by presenting the data from the codes in a consistent format so that the designer may work as readily with one code as with the other. For example, the authors have adopted the names *3-Hour*, *2-Hour*, and so on, for the Construction Types. These names are based on the required fire-resistance ratings of the structural loadbearing frame in each Type and are used to overcome inconsistencies in nomenclature between the codes. In addition, the adjustments permitted in each code for allowable area, height, inclusion of fire sprinklers, and other considerations have been precalculated for easy reference.

One difference between the codes that was not possible to resolve relates to the determination of allowable area. For the International Building Code, tabulated values in the height and area tables are for the *total area of all floors of the building combined.* For the National Building Code of Canada, the tabulated values are for the *area of any single floor.* When working with these tables, be sure to apply the indicated values appropriately.

***Use these indexes to find the height and area limitations table for the building code and Occupancies you are working with.***

**INTERNATIONAL BUILDING CODE**

| Occupancy | Height and Area Limits |
|---|---|
| A-1: Assembly, Theaters | 388–389 |
| A-2: Assembly, Food and Drink Establishments | 390–391 |
| A-3: Assembly, Miscellaneous | 392–393 |
| A-4: Assembly, Indoor Arenas | 394–395 |
| A-5: Assembly, Outdoor Arenas | 396–397 |
| B: Business | 398–399 |
| E: Educational | 400–401 |
| F-1: Factory, Moderate Hazard | 402–403 |
| F-2: Factory, Low Hazard | 404–405 |
| H-1: High-Hazard, Detonation | 406–407 |
| H-2: High-Hazard, Accelerated Burning | 408–409 |
| H-3: High-Hazard, Combustibles | 410–411 |
| H-4: High-Hazard, Corrosives and Toxics | 412–413 |
| H-5: High-Hazard, Hazardous Production Materials | 414–415 |
| I-1: Institutional, Residential Care | 416–417 |
| I-2: Institutional, Medical and Custodial Care | 418–419 |
| I-3: Institutional, Detention and Security | 420–421 |
| I-4: Institutional, Day Care | 422–423 |
| M: Mercantile | 424–425 |
| R-1: Residential, Hotels and Motels | 426–427 |
| R-2: Residential, Multifamily | 428–429 |
| R-3: Residential, Miscellaneous | 430–431 |
| R 4: Residential, Residential Care | 432–433 |
| S-1: Storage, Moderate Hazard | 434–435 |
| S-2: Storage, Low Hazard | 436–437 |
| S-2: Open Parking Garages | 438–439 |
| U: Utility and Miscellaneous | 440–441 |

See pages 6–12 for more information on Occupancy classifications in the International Building Code.

# HEIGHT AND AREA LIMITATIONS

Each code has seemingly endless exceptions to its own basic height and area limitations. The most important exceptions deal with adjustments permitted in exchange for automatic sprinkler systems. These adjustments have been incorporated fully into the following tables. Other important conditions are noted in the accompanying text. Occasionally, exceptions are so complex that they cannot reasonably be incorporated into these pages; for these, you are directed to the code itself. Some exceptions were deemed by the authors to be so minor as not to warrant their inclusion here. For this reason, you must carry out a thorough investigation of the building code itself as a building design progresses to its developmental stage.

The following pages provide information on additional topics closely related to determining building height area. You should review these pages to the extent that these conditions apply to your building design:

- Mixed-Occupancy Buildings: pages 368–371
- Mezzanines, Floor Openings, and Atriums: pages 372–373
- Fire sprinklers, fire areas and compartments, exterior walls, and fire walls: pages 374–375

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| Occupancy | Height and Area Limits |
|---|---|
| A-1: Assembly, Theaters | 444–445 |
| A-2: Assembly, Miscellaneous | 446–447 |
| A-3: Assembly, Arenas | 448–449 |
| A-4: Assembly, Open Air | 450–451 |
| B-1: Detention | 452–453 |
| B-2: Medical Treatment | 454–455 |
| B-3: Care | 456–457 |
| C: Residential | 458–459 |
| D: Business and Personal Services | 460–461 |
| E: Mercantile | 462–463 |
| F-1: Industrial, High-Hazard | 464–465 |
| F-2: Industrial, Medium-Hazard | 466–467 |
| F-3: Industrial, Low-Hazard | 468–469 |
| F-3: Open-Air Garages | 470–471 |

See pages 13–14 for more information about Occupancy classifications in the National Building Code of Canada.

Single buildings frequently accommodate more than one type of Occupancy—for example, retail space on the ground floor of a multistory office building, restaurants, bars, and meeting rooms in a hotel, or parking garages beneath commercial or residential occupancies. Use the following guidelines for the design of such mixed-occupancy structures.

### Construction Types for Mixed-Occupancy Buildings

When a building contains more than one Occupancy, the model codes generally require that the structure remain a single Construction Type throughout. So, for example, a building with both Assembly and Residential Occupancies usually must be constructed to a single Construction Type that satisfies the height and area restrictions of both Occupancies. It cannot be constructed to one Construction Type meeting the requirements of the Assembly portion and another Type meeting the requirements of the Residential portion. However, both codes also provide exceptions to this general rule, the most important of which are noted on the following pages.

## INTERNATIONAL BUILDING CODE

When two or more Occupancies are combined in one building, the International Building Code allows these mixed-use conditions to be treated as *Nonseparated, Separated,* or *Accessory Occupancies*.

### Nonseparated Occupancies

When occupancies are Nonseparated, they are permitted to remain open to each other and there are no requirements for fire-rated separations between them. In this case, the allowable building height and area are determined by applying the most restrictive limits of any of the Occupancies throughout the entire building. For example, in a building including nonseparated B Business, M Mercantile, and A Assembly Occupancies, the designer would consult the height and area limits for each of these occupancies and then apply the most restrictive limits to the building as a whole.

Within each Nonseparated Occupancy area, occupant load calculations, egress configuration, and other code restrictions are applied according to the requirements for that particular Occupancy.

When the code height and area limits are generous enough to permit the treatment of a mixed-occupancy building as Nonseparated, this is the simplest method to apply and the one that affords the greatest design flexibility within the building.

### Separated Occupancies

When mixed Occupancies within a single building are treated as Separated, the code defines fire-resistance rating requirements for walls, doors, other openings, and floor/ceiling assemblies between these Occupancies. These separations reduce the risk that fire and smoke in one area of the building can spread rapidly to others. In exchange for this added protection, larger overall building areas and taller heights are permitted.

The degree of separation required in a Separated Occupancy building depends on the particular Occupancies involved. Consult the accompanying table for preliminary design requirements. Occupancies listed together in the same row do not require separation even when they occur together within a Separated Occupancy building. Occupancies listed in separate rows require fire separations, with ratings ranging from 1 to 2 hours, between them. For example, in a building including B Business, M Mercantile, and A Assembly Occupancies, the B and M Occupancies may remain completely open to each other, but the Assembly Occupancy area must be separated from these others by fire-resistance-rated construction and rated doors and other openings.

In a Separated Occupancy building, each Occupancy area is required to conform to its own height limitations, both in number of stories and in feet (or meters) above grade. For example, in a four-story Separated Occupancy building, where one of the Occupancy's height limitations restricts it to no more than two stories, that Occupancy may only be located on the first or second floor of the building.

**SEPARATION REQUIREMENTS IN SEPARATED OCCUPANCY BUILDINGS**

| Occupancies | Separation |
|---|---|
| A, E | No separation required between these occupancies |
| I-1, I-3, I-4 | No separation required between these occupancies |
| I-2 | Separation required from all other occupancies |
| R | Separation required from all other occupancies |
| F-2, S-2, U | No separation required between these occupancies |
| B, F-1, M, S-1 | No separation required between these occupancies |
| H | Consult the code. |

Some other Occupancy, with height limits permitting four stories, may be located on any floor.

Considering building area limits, where an entire building floor contains only a single Occupancy, the area of that floor is limited by the restrictions for that Occupancy. Where a floor shares two or more Occupancies, the allowable area determination for that floor is based on a proportional calculation as follows:

**1.** For each Occupancy, divide its proposed area on the floor by the maximum area permitted by the code to get a decimal fraction.

**2.** Add the fractional results for each Occupancy on the floor.

**3.** The sum total must not exceed 1.

For example, consider a four-story university building, sprinklered, of Type II-A Construction. The proposed footprint of the building is 85,000 sq ft. On the first floor are three 5000-sq-ft auditoriums classified as Group A-3 Assembly and 70,000 sq ft of classroom space classified as Group B Business. In the height and area limit tables on pages 392–393 and 398–399 the allowable single-floor areas in multifloor buildings for these two Occupancies are 46,500 sq ft for the Assembly Occupancy and 112,500 sq ft for the Business Occupancy (these figures are read from the bottom row of the height and area limit tables). To check the floor area, first divide the proposed area by the allowable area for each Occupancy:

Group A-3, area on floor 1:

$$\frac{3 \times 5000 \text{ sq ft } \textit{proposed}}{46{,}500 \text{ sq ft } \textit{allowed}} = 0.32$$

Group B, area on floor 1:

$$\frac{70{,}000 \text{ sq ft } \textit{proposed}}{112{,}500 \text{ sq ft } \textit{allowed}} = 0.62$$

Then sum the fractions and compare to 1:

$$0.32 + 0.62 = 0.94 < 1 \text{ OK}$$

In this case, the sum of the fractions is less than 1, and this combination of Occupancies is within allowable area limits. In a building with more than one floor, this check must be performed for each floor. (These additional checks are omitted in this example.)

For Separated Occupancy buildings over three stories in height, an additional check must be made to verify area limits for the building as a whole. In this case, a similar proportional calculation is performed, but comparing the proposed area on all floors to the allowable area on all floors. Continuing with the example above, assume that the second through fourth floors of the building each contain 85,000 sq ft of classroom and office space all classified as Group B Business. Consulting again the height and area limit tables, the total allowable area on all floors for these two Occupancies is 139,500 sq ft for the Assembly Occupancy and 337,500 sq ft for the Business Occupancy (these figures are read from the row corresponding to the proposed story height of the building). First, for each Occupancy, divide the proposed area on all floors by its allowable area on all floors:

Group A-3, area on all floors:

$$\frac{3 \times 5000 \text{ sq ft } \textit{proposed}}{139{,}500 \text{ sq ft } \textit{allowed}} = 0.11$$

Group B, area on all floors:

$$\frac{70{,}000 \text{ sq ft} + 3 \times 85{,}000 \text{ sq ft } \textit{proposed}}{337{,}500 \text{ sq ft } \textit{allowed}} = 0.96$$

Then sum the fractions and compare to 1:

$$0.11 + 0.96 = 1.07 > 1 \text{ NOT OK}$$

In this case, considering the area on all floors of the building, the sum of the fractions exceeds 1 and the proposed building is not within the code's area limits for the proposed mix of Occupancies. To solve this problem, the building area must be reduced, the mix of Occupancies must be adjusted, or a Construction Type with greater allowable area must be selected.

## Accessory Occupancies

Occupancies of limited area that are ancillary to another primary Occupancy may be treated as Accessory to the primary Occupancy. This approach may result in relaxed separation requirements and/or reduced impact on building height and area limits in comparison to other approaches to mixed Occupancies.

One or more Occupancy areas may be considered Accessory when, in total, they occupy no more than 10% of the area of the floor on which they are located. In most cases, no separation is required between Accessory and primary Occupancy areas, and building height and area requirements are governed by the primary Occupancy. Occupant load, egress, and sprinkler requirements for each Occupancy are applied individually to each area. Additionally, Accessory areas themselves may not exceed the unsprinklered height and area limits (regardless of whether sprinklers are present) for their particular Occupancy type. Certain Occupancies, such as High-Hazard, may not be treated as Accessory to others, regardless of size.

*Incidental Accessory Occupancies* are a list of particular Accessory Occupancies considered to have special fire- or life-safety risks. Though they may be treated as Accessory for the purposes of height and area calculations, they must also meet specific fire separation and protection requirements. Examples of such Occupancies include certain furnace rooms, boiler rooms, incinerator rooms, machinery rooms, paint shops, laboratory areas, vocational shop areas, laundry rooms, waste and linen collection rooms, fire pump rooms, and others. See the code for more details.

## Horizontal Building Separations

The International Building Code recognizes unique Occupancy combinations that result, for purposes of code analysis and compliance, in two separate buildings, using different Construction Types, one constructed above the other. The advantage to these scenarios is the possibility of building to a greater height with less expensive construction systems than would otherwise be permitted. These scenarios are summarized below. See the code for more details.

### *3-Hour Horizontal Building Separation*

The building up to the first story above grade is constructed of 3-Hour (Type IA) Construction and is separated from the construction above by a 3-hour rated horizontal assembly. The following conditions apply:

- The first story and any stories below grade must be fully sprinklered and may include A, B, M, R, and S-2 Occupancies.
- The portions of the structure above the first story may include B, M, R, and S Occupancies. Any Construction Type may be used, as long as height and area requirements are satisfied.
- For the upper Occupancies, allowable height in stories is measured from the horizontal separation between the first and second stories.
- Maximum allowable building height in feet (or meters), for all parts of the structure, is measured from the ground plane.

### *R Occupancy Over Parking*

The building up to the first story above grade is constructed of at least 2-Hour (Type 1B) or Mill (Type IV) Construction and is separated from the construction above by a rated horizontal assembly (usually 1-hour). The following conditions apply:

- The first story and any stories below grade must be fully sprinklered and may include only Group S-2 parking.
- The portions of the structure above the first story may include any R Occupancy. Any Construction Type may be used, as long as height and area requirements are satisfied.
- For the R Occupancy, allowable height in stories is measured from the horizontal separation above the parking.
- Allowable building height in feet (or meters), for all parts of the structure, is measured from the ground plane.

### *A, I, B, M, and R Occupancies Over Parking*

An open parking garage is built to the Construction Type and height and area requirements of the table on pages 338–339. A rated horizontal separation (usually 2-hour) is required between the parking garage and the Occupancies above. The following conditions apply:

- The Construction Type for lower portions of the structure must be at least as fire-resistant as for the portions above.
- The portions of the structure above the parking may include A, I, B, M, and R Occupancies. Any Construction Type may be used, as long as height and area requirements are satisfied.
- For the upper Occupancies, allowable height, in feet (or meters) and stories, is measured from the ground plane.

### *Parking Over B and M Occupancies*

The building up to the first story above grade is a Noncombustible Construction Type and is separated from the construction above by a 2-hour rated horizontal assembly. The following conditions apply:

- The first story and any stories below grade may include B and M Occupancies, as long as height and area requirements are satisfied.
- The Construction Type for lower portions of the structure must be at least as stringent as for the portions above.
- Above the first story, an Occupancy S-2 open parking garage is built to the Construction Type and height and area requirements of the table on pages 338–339.
- For the parking portion of the structure, allowable height, in feet (or meters) and stories, is measured from the ground plane.

### *Open Parking Over Enclosed Parking*

The building up to the first story above grade is a Noncombustible Construction Type and is separated from the construction above by a horizontal assembly with the same rating required for any other floor in that Construction Type.

- The first story and any stories below grade may include only Group S-2 enclosed parking.
- The Construction Type for lower portions of the structure must be at least as stringent as for the portions above.
- Above the first story, an Occupancy S-2 open parking garage is built to the Construction Type and height and area requirements of the table on pages 338–339.
- For the upper portion of the structure, allowable height, in feet (or meters) and stories, is measured from the ground plane.

## NATIONAL BUILDING CODE OF CANADA

### Separated Occupancies

In the National Building Code of Canada, distinct Occupancies within a building must be separated from each other by fire-resistant wall and floor assemblies. Fire-resistance rating requirements for these separations vary from 1 to 2 hours, except for F-1 High-Hazard Industrial Occupancies, for which 2- to 3-hour separations from other Occupancies are required. In addition, the following limitations apply:

- A building containing an F-1 High-Hazard Industrial Occupancy may not contain any A Assembly, B Detention, Treatment, or Care, or C Residential Occupancies.
- A building containing an F-2 Medium-Hazard Industrial Occupancy may not contain more than one C Residential Suite or Occupancy.

### Accessory Occupancies

Accessory Occupancies are recognized, in which the area of one or more Occupancies does not exceed 10% of the total area on a floor. Accessory Occupancies are not required to be separated from the major Occupancy and are not considered in the determination of height and area limits for the building. High- and Medium-Hazard Industrial Occupancies may not be treated as accessory to other occupancies.

### Mixed Construction Types

In mixed-occupancy buildings, the most restrictive Construction Type, height, and area requirements of any of the major Occupancies are applied to the whole building. However, in cases where one Occupancy Type occurs fully above or below another, the code also permits an alternative treatment in which each portion of the structure may meet the Construction Type requirements for that portion's Occupancy, while the more restrictive height and area requirements of either Occupancy are applied to the building as a whole. This option allows the possibility of a single building of multiple Construction Types—for example, combustible residential units above a noncombustible commercial first story.

### Basement Separations

A fire separation is required between basements and floors above grade. For a single-level basement, this separation must have a fire-resistance rating of at least 45 minutes and not less than that required for floor assemblies as determined by building Construction Type requirements. For multilevel basements, this fire separation must be 2 to 3 hours, depending on the basement Occupancies. The floors within a multilevel basement cannot have less than a 45-minute fire-resistance rating.

### Parking Garages and Mixed Occupancies

When a basement is used primarily as a parking garage for vehicle storage only (exclusive of vehicle servicing or fueling), it may be considered as a separate building, provided that the separation between the garage and the Occupancies above, as well as the portions of the garage walls above grade, are constructed of noncombustible construction with a 2-hour fire-resistance rating. In this case, the structure above the garage is subject to its own Construction Type, height, and area requirements. In some cases, the garage may also require sprinklers. See the code for details.

### Small Buildings

The National Building Code of Canada includes distinct requirements for *Housing and Small Buildings*, that is, buildings not greater than 600 m$^2$ (6458 sq ft) in horizontal extent, not greater than three stories in height, and serving only C Residential, D Business and Personal Services, E Mercantile, and F-2 or F-3 Medium- or Low-Hazard Industrial Occupancies. For preliminary design purposes, assume the following construction requirements. See the code for details:

- ¾-Hour Combustible or Noncombustible Construction is required (with some exceptions for roof and mezzanine construction).
- Depending on the proximity to other buildings, exterior walls may be required to be of Noncombustible Construction.
- Firewalls, used to create separate buildings, must be of Noncombustible Construction.
- Separation walls between two side-by-side C Residential Occupancies may be 1-hour rated Combustible or Noncombustible Construction.
- C Residential Occupancies must be separated from other Occupancies by assemblies with 1- to 2-hour fire-resistance ratings. Not more than one C Residential Occupancy suite may be mixed with F-2 Medium-Hazard Industrial Occupancy.
- In C Residential Occupancies, no fire-rated separation is required between a parking garage serving a single dwelling and that dwelling unit, provided that the construction between the dwelling unit and the garage is constructed as a barrier to the passage of gas and exhaust fumes, and doors from the garage do not open into rooms intended for sleeping.
- Sprinklers are not required but may be used as a tradeoff for various other code requirements.

## MEZZANINES

A *mezzanine* is an intermediate platform located between the floor and ceiling of a room. Under both model building codes, mezzanines of limited area are not counted toward the number of floors or the area limits of a building. However, the area of a mezzanine is considered when calculating occupant loads and egress requirements.

### International Building Code

In the International Building Code, the area of a mezzanine generally may not exceed one-third of the open area of the room in which it is located. However, mezzanines in fully sprinklered buildings of Noncombustible Construction may be up to one-half of the open room area, and mezzanines in certain Industrial Occupancies may be up to two-thirds of this area. (Enclosed portions of the room in which mezzanines are located are not included in these calculations.)

Generally, mezzanines must remain open to the room in which they are located. Exceptions to this requirement include portions of a mezzanine with an occupant load of 10 or less; portions not exceeding 10% of the mezzanine area; mezzanines with two means of egress, at least one of which leads directly to an exit; and mezzanines in certain industrial or low-rise nonhazardous Occupancy buildings.

Mezzanine egress requirements are determined as for any other room or space within a building, considering, for example, the number of occupants, Occupancy Type, common path of travel, travel distance, and so on. See the discussion of Exit Access, beginning on page 266, for more information

Mezzanines are subject to the same Construction Type requirements as the building in which they are located.

### National Building Code of Canada

In the National Building Code of Canada, the area of a mezzanine may not exceed 40% of the open area of the room in which it is located, with enclosed portions of the room not included in this calculation. A mezzanine is required to remain open to the room, except that portions of the mezzanine not exceeding 10% of the open area of the room may be enclosed if direct line-of-sight communication between the enclosed mezzanine area and the open floor area below is maintained. In some cases, a mezzanine may be constructed to a lesser fire resistance than the floor on which it is located; see pages 378–379 for more information.

Means of egress requirements for mezzanines are generally determined as for any other floor area. However, this code also provides a variety of exceptions for mezzanine egress related to number of exits, travel distance limits, mezzanine area, and occupancy. See the code for more information.

For mezzanines with more than one level, only the first level may be omitted when determining the total number of building floors or area.

## FLOOR OPENINGS AND ATRIUMS

In both model codes, openings that create atmospheric connections between floors within a building, other than enclosed exit stairways, elevator hoistways, service shafts, and other such protected vertical structures, are subject to restrictions intended to limit the rapid spread of smoke or fire between floors in the event of a building fire.

### International Building Code

Floor openings are permitted in the following circumstances:

- Openings within dwelling units not connecting more than four floors
- Openings between a floor and its mezzanines
- Openings for exit access stairways not connecting more than two floors, providing no more than one-half of the required exit capacity for those floors, in other than Group H or I Occupancies
- Openings for exit access stairways between the first and second floors above grade in sprinklered buildings in other than Group H or I Occupancies (including up to 100% of the required egress capacity)
- In sprinklered buildings, openings for escalators and for stairs not considered part of the means of egress (sometimes limited to those connecting not more than four floors)
- Openings not connecting more than two floors, not part of the exit or exit access system, and not connected to any corridor on an unsprinklered floor or to any corridor in a Group I or R Occupancy
- Openings for parking garage automobile ramps or elevator hoistways not connected to other occupancies
- Openings protected with fire-rated shutters or doors that close automatically in the case of fire

Floor openings with special smoke and fire control provisions, called *atriums*, are also permitted, provided that the following requirements are met:

- Activities on the floor level of the atrium are restricted to those with a low fire hazard, unless that area is protected by sprinklers.

- Buildings containing atriums must be sprinklered throughout, except that areas adjacent to and above an atrium need not be sprinklered when separated from the atrium by 2-hour rated assemblies. Additionally, atrium ceilings more than 55 ft (17 m) above the atrium floor need not be sprinklered.
- Atriums connecting more than two floors must be provided with a mechanical smoke control system designed to protect occupants from smoke and toxic gasses during a fire emergency.
- Atriums must be separated from adjacent spaces by 1-hour rated walls, except that up to three floors may be open to an atrium as long as the smoke control system design accounts for the volume of the connected areas. Walls separating atriums from adjacent spaces may include glass when the glass areas are protected with sprinkler systems designed to completely wet the glass surfaces when activated, or they may be constructed of glass block with not less than a ¾-hour fire-resistance rating.
- Except at its lowest level, portions of exit access travel within atrium spaces may not exceed 200 ft (61 m).

## National Building Code of Canada

In the National Building Code of Canada, openings between floors are called *interconnected floor spaces* and are permitted as follows:

- Floor openings may connect the ground floor of a building with either the floor directly above or below (but not both) if the opening size is limited as necessary for an open stairway, inclined moving walk, or escalator; the interconnected space contains only A, D, E, F-2, or F-3 Occupancies; and the building area is no more than one-half of its maximum code-permitted area.
- Floor openings as above, but of unlimited area, are permitted if the interconnected floor space is fully sprinklered.
- Floor openings for escalators or inclined moving walks, not exceeding 10 $m^2$ (108 sq ft) in area, may connect any floors with A, D, or E Occupancies in fully sprinklered buildings.
- Floor openings may connect any two floors in a B-1 Detention Occupancy building.
- Floor openings are permitted for vehicular ramps in parking garages.
- Floor openings are permitted in special industrial buildings where necessary for the flow of materials for the manufacturing processes taking place.

More extensive interconnected floor spaces are also are permitted in fully sprinklered buildings constructed of Noncombustible or Heavy Timber Construction meeting all of the following requirements:

- A mechanical smoke exhaust system serving the interconnected floor spaces is provided.
- The quantity of combustible contents located in interconnected floor spaces is limited.
- Exit access ways are separated from interconnected floor spaces by fire separations with a fire-resistance rating not less than the required rating for floor assemblies.
- Exits opening into interconnected floor spaces are protected by vestibules. Elevator shafts that open into interconnected floor spaces, as well as spaces on higher floors, are protected by vestibules either on all interconnected floor space floors or all floors above.
- Sleeping rooms in Group B-2 Care or Detention Occupancies are not located within interconnected floor spaces.

Occupancy areas on a floor may be considered not part of an interconnected floor space if they are separated from that space by walls with a fire-resistance rating equal to that of the floor. For example, where the code allows only certain Occupancies to occur within interconnected floor space, other Occupancies can occur on the same floor if they are separated as required.

## FIRE SPRINKLERS

In addition to the sprinkler requirements incorporated into the height and area tables beginning on page 385, both model building codes require sprinklers in a variety of other circumstances.

In the International Building Code:

- Most buildings with occupied floors more than 55 ft (16.8 m) above the lowest ground level must be sprinklered throughout. Buildings with occupied floors more than 75 ft (23 m) above the lowest ground level must meet additional fire safety requirements. See page 291 for more information.
- Most buildings with occupied floors more than 30 ft (9.1 m) below the lowest grade must have all exit levels and below grade-levels sprinklered. For more information on underground building requirements, see page 292.
- Stories above or below grade without openings to the exterior, or with openings limited in size or extent (see the code for details), must be sprinklered.

In the National Building Code of Canada:

- *High buildings*, that is, buildings with occupied floors 18 m (59 ft) to 36 m (118 ft) above grade, must be sprinklered throughout. See pages 292–293 for information on high building requirements.
- Where a story is required to be sprinklered throughout, all stories below that story (including both above- and below-ground stories) must also be sprinklered.
- Normally, all basements levels must be sprinklered. However, if the ground-level floor of a building is not required to be sprinklered, the following exceptions may be applied: Basement levels may remain unsprinklered if they are subdivided by fire separations into compartments not greater than 600 m$^2$ (6460 sq ft) in area. Or, a first story below grade may remain unsprinklered if it contains only residential Occupancies and has direct access from a public street in the form of doors, windows, or other acceptable openings.

## FIRE AREAS AND FIRE COMPARTMENTS

In the International Building Code, fire-resistance rated walls and floor/ceiling assemblies may be used to subdivide portions of a building into so-called *fire areas*. Fire area size is one factor in determining when fire sprinklers are required for a particular Occupancy. In some circumstances, limiting the size of a fire area can eliminate the need for sprinklering.

Fire area size is determined by measuring the floor area surrounded by fire-rated wall or floor assemblies. For example, in a single-story building with the interior undivided, the fire area is calculated as the entire floor area of the building. In a multistory building, where interior walls and floor/ceiling assemblies are all unrated, the fire area is calculated as the sum of the areas of all floors. On the other hand, in this second example, if floor/ceiling assemblies are constructed with sufficient fire resistance, each floor may be considered as a separate, smaller fire area. The floor area of mezzanines is included in fire area calculations, as is the combined area of floors connected by unprotected openings.

Even when a fire area requirement applies only to one particular occupancy, fire area is measured including all areas that are not separated by rated assemblies. For example, consider a single-story office building, 15,000 sq ft in area, including a 1000-sq-ft A-3 Assembly Occupancy space and the remainder B Occupancy. According to the information provided with the table on pages 392–393, A-3 Occupancies with a fire area greater than 12,000 sq ft must be sprinklered. In this example, if the assembly and business areas are not properly separated, the fire area is the area of the entire floor, 15,000 sq ft, and the entire floor must be sprinklered. Alternatively, if adequately rated wall assemblies are used to separate the assembly and business areas, the fire area of the assembly space is only 1000 sq ft, and sprinklers are no longer required.

Fire-resistance rating requirements for separations between fire areas range from 1 to 4 hours, depending on the type of Occupancy involved. For preliminary purposes, a 2-hour rating may be assumed for nonhazardous Occupancies.

The National Building Code of Canada defines *fire compartments* as areas surrounded by fire-resistance rated wall and floor assemblies. Fire compartment size can be a factor, for example, in the limits placed on the presence of combustible finish materials in buildings of Noncombustible Construction types or the maximum area of openings in fire separation walls or exterior walls. Fire compartment size may also affect requirements for sprinklers in certain Occupancy conditions.

## EXTERIOR WALLS

Exterior walls must be constructed to resist fires originating from within the building itself as well as from nearby structures. In cases where buildings are close to property lines or other structures, the risk of exposure to fire from adjacent buildings may create more stringent requirements for limits on combustibility or fire resistance of exterior walls of a building than would otherwise be required for its own Construction Type.

Specific requirements vary with the type of construction, the Occupancies within the building, the presence of sprinklers, the extent of openings within the wall, and the distance between buildings. In the International Building Code, excluding High-Hazard Occupancies, fire-resistance rating requirements for exterior walls of buildings less than 60 ft (18 m) apart range from 0 to 1 hour, and for buildings separated by less than 20 ft (6 m) they range from 1 to 2 hours. In the National Building Code of Canada, exterior wall fire-resistance rating requirements range from 45 minutes to 2 hours, with distances between buildings varying from as little as 12 m (39 ft) to as much as 140 m (459 ft), depending especially on the extent of openings in the walls.

In addition, as the distance between buildings decreases, the extent of windows, doors, and other unprotected openings permitted in exterior walls also declines. Consult the code for details.

## FIRE WALLS

*Fire walls* are assemblies used to divide structures into two or more parts such that the construction on either side of the assembly may then be considered a separate building for the purposes of determining its Construction Type and allowable height and area. In this way, a building of virtually any horizontal extent can be built, so long as it is subdivided by fire walls into self-contained parts that individually comply with code limitations. (Both model codes also recognize certain circumstances in which horizontal separations can be used to create two virtual buildings, one above the other. See pages 370–371 for more information.)

Fire walls require a fire-resistance rating of 2 to 4 hours, depending on the Occupancies being separated. They must be constructed either as two separate walls, each independently supported by the structures on opposite sides, or as one wall that can remain standing in the event of a structural collapse on either side. The National Building Code of Canada also permits a single fire wall to be supported by a noncombustible structure when that structure has a fire-resistance rating at least as great as that required for the wall.

Fire walls must extend continuously from one exterior wall of the structure to the other and, in most circumstances, from the building foundation to the roof. (Where the codes permit horizontal separation creating two buildings, one above the other, the bottom of a fire wall in the upper building may terminate at the separation.) And they may be vertical structures only. That is, horizontal floor/ceiling assemblies may not be part of fire wall structures.

The International Building Code requires fire walls to be of Noncombustible Construction, unless separating solely Type V Wood Light Frame structures on both sides. In the National Building Code of Canada, fire walls with a 4-hour fire-resistance rating must be constructed of masonry or concrete. Walls with a 2-hour rating may be constructed of other materials as long as their durability and stability during fires can be ensured.

Depending on the fire resistance of the building's exterior construction, fire walls may be required to project beyond exterior walls and/or roofs a distance ranging from 6 to 36 in. (150 to 900 mm) to limit the chance of fire jumping from one side of the wall to the other. Where exterior walls and roofs have sufficient fire resistance themselves, fire walls may be permitted to terminate at these boundaries without projecting beyond. For the same reason, openings in exterior walls or roofs within certain distances of fire walls may be restricted.

Within fire walls themselves, openings, most commonly for doors, must be fire rated. Each opening must meet specified size limits, and the area of all openings taken together must not exceed 25% of the wall's total area. Where fire walls coincide with property lines (also known as *party walls*), the International Building Code does not permit openings of any type.

## INTERNATIONAL BUILDING CODE

This section summarizes the fire-resistance rating and construction requirements for Construction Types in the International Building Code. Once you have determined an appropriate Construction Type for a project, based on the height and area tables on pages 388–441, use this section to relate the Construction Type to complete systems of construction. The table on these two facing pages consolidates and simplifies the fire-resistance requirements for each Construction Type. The pages following this chart define each Construction Type in terms of specific structural systems, materials, and minimum thicknesses of components necessary to meet the required fire-resistance rating. The values in the table below may be modified as follows:

**Reduction in 1-Hour Rated Construction:** Where building height and area are read from the Unsprinklered column of the height and area tables in this book, and a sprinkler system is not otherwise a code requirement, the use of sprinklers may be applied toward a reduction in the protection requirements for buildings of any 1-Hour Construction Type. That is, when reading height and area from *unsprinklered* 1-Hour Noncombustible (Type II-A), 1-Hour Ordinary (Type III-A), or 1-Hour Wood Light Frame (Type V-A) Construction, you may fully sprinkle the building and then use the Construction Type requirements of Unprotected Noncombustible (Type II-B), Unprotected Ordinary (Type III-B), or Unprotected Wood Light Frame (Type V-B) Construction, respectively. Exterior bearing wall fire-resistance requirements are not reduced. However, wherever the code requires sprinklers for any other reason, such as height and area adjustments or Occupancy and fire area restrictions, this construction type reduction cannot be applied.

**Exterior Bearing Walls:** In addition to the requirements indicated in the table on these two facing pages, see also the discussion of fire-resistance requirements for exterior walls, page 375, for information regarding protection of exterior walls when in close proximity to other buildings.

**Structure Supporting Roofs Only:** In 3-Hour and 2-Hour (Type I-A and Type I-B) Construction, fire-resistance requirements for the structural frame and interior bearing walls supporting roofs only may be reduced by 1 hour. Roof construction and exterior bearing wall fire-resistance requirements are not reduced.

**Roof Construction:** Roof structures 20 ft (6 m) or more above the floor below may be unprotected except in F-1, H, M, and S-1 Occupancies. Heavy Timber Construc-

**INTERNATIONAL BUILDING CODE FIRE-RESISTANCE RATING REQUIREMENTS**

| | Noncombustible | | | |
|---|---|---|---|---|
| **CONSTRUCTION TYPE** | **3-Hour (page 380)** | **2-Hour (page 380)** | **1-Hour (page 381)** | **Unprotected (page 382)** |
| **INTERNATIONAL BUILDING CODE NOMENCLATURE** | **Type I-A** | **Type II-A** | **Type II-A** | **Type II-B** |
| **STRUCTURAL FRAME INCLUDING COLUMNS, GIRDERS, TRUSSES** | 3 | 2 | 1 | 0 |
| **EXTERIOR BEARING WALLS** | 3 | 2 | 1 | 0 |
| **INTERIOR BEARING WALLS** | 3 | 2 | 1 | 0 |
| **FLOOR CONSTRUCTION** | 2 | 2 | 1 | 0 |
| **ROOF CONSTRUCTION** | 1½ | 1 | 1 | 0 |
| **PARTY WALLS AND FIRE WALLS** | 2–4 | 2–4 | 2–4 | 2–4 |
| **EXIT STAIR, EXIT PASSAGEWAY, AND SHAFT ENCLOSURES** | 2 | 2 | 2-hr connecting 4 stories or more<br>1-hr connecting less than 4 stories | |
| **EXIT ACCESS CORRIDORS (PAGE 269)** | 0–1 | 0–1 | 0–1 | 0–1 |
| **MALL TENANT SPACE SEPARATIONS** | 1 | 1 | 1 | 1 |
| **DWELLING UNIT AND SLEEPING UNIT SEPARATIONS** | 1 | 1 | 1 | 1½ |
| **OTHER NONBEARING PARTITIONS** | 0 (noncombustible) | | | |

tion is permitted wherever a roof structure with a fire-resistance rating of 1 hour or less is required, in all occupancies.

**Enclosures for Corridors and Exits:** For more information on corridor enclosure requirements, see page 269, and for exit enclosures, see pages 274–275.

**Mall Tenant Spaces:** Individual tenant spaces in covered mall buildings must be separated from each other (but not from the mall space) by wall and floor assemblies with a 1-hour fire-resistance rating.

**Dwelling Unit and Sleeping Unit Separations:** Walls separating dwelling units or sleeping units in I-1 Residential Care, R-1 Hotel and Motel, R-2 Multifamily, and R-3 Miscellaneous Residential Occupancies must be separated from other such units and from other Occupancies by wall and floor assemblies with a 1-hour fire-resistance rating. This requirement may be reduced to a ½-hour rating in any noncombustible, unprotected Construction Type, provided that the building is fully sprinklered.

**Tall Buildings:** For buildings with occupied floors more than 75 ft (23 m) above grade, with roofs not higher than 420 ft (128 m), and equipped with enhanced sprinkler systems, Construction Type and rated assembly requirements may be adjusted as follows:

- Buildings of Type I-B Construction may be built to the height and area limits of Type I-A Construction, except that columns supporting floors must be built to the requirements of Type I-A Construction.
- In other than Group F-1, M, and S-1 Occupancies, buildings of Type II-A Construction may be built to the height and area limits of Type I-B Construction.
- Shafts for other than exits and elevators may be enclosed with 1-hour fire-resistance rated construction when the interiors of the shafts themselves are protected with an automatic sprinkler system.

These provisions do not apply to open parking garages, airport traffic control towers, outdoor sports arenas, and some unusually tall low- and medium-hazard industrial buildings. For special egress system and smoke control requirements in tall buildings, see High-rise Building Egress, page 291.

**Substitution of Higher-Rated Construction Types:** Height and area limits define *minimum* levels of fire protection but do not preclude the use of more fire-resistant systems. For example, where the building code permits a building of Unprotected Combustible (Type V-B) Construction, any other Construction Type is also permitted. Alternatively, where 1-Hour Combustible Construction is required, 1-Hour or greater Noncombustible Construction is also permitted.

| **Mixed Combustible/Noncombustible** | | | **Combustible** | | |
|---|---|---|---|---|---|
| **Ordinary** | | **Mill** | **Wood Light Frame** | | |
| **1-Hour (page 382)** | **Unprotected (page 382)** | **(page 382)** | **1-Hour (page 384)** | **Unprotected (page 384)** | **CONSTRUCTION TYPE** |
| **Type III-A** | **Type III-B** | **Type IV-HT** | **Type V-A** | **Type V-B** | **INTERNATIONAL BUILDING CODE NOMENCLATURE** |
| 1 | 0 | Heavy Timber | 1 | 0 | **STRUCTURAL FRAME INCLUDING COLUMNS, GIRDERS, TRUSSES** |
| 2 Noncombustible | 2 Noncombustible | 2 Noncombustible | 1 | 0 | **EXTERIOR BEARING WALLS** |
| 1 | 0 | 1 or Heavy Timber | 1 | 0 | **INTERIOR BEARING WALLS** |
| 1 | 0 | Heavy Timber | 1 | 0 | **FLOOR CONSTRUCTION** |
| 1 | 0 | Heavy Timber | 1 | 0 | **ROOF CONSTRUCTION** |
| 2–4 | 2–4 | 2–4 | 2–4 | 2–4 | **PARTY WALLS AND FIRE WALLS** |
| 2-hr connecting 4 stories or more<br>1-hr connecting less than 4 stories | | | | | **EXIT STAIR, EXIT PASSAGEWAY, AND SHAFT ENCLOSURES** |
| 0–1 | 0–1 | 0–1 | 0–1 | 0–1 | **EXIT ACCESS CORRIDORS (PAGE 269)** |
| 1 | 1 | 1 | 1 | 1 | **MALL TENANT SPACE SEPARATIONS** |
| 1 | 1½ | 1 | 1 | 1½ | **DWELLING AND SLEEPING UNIT SEPARATIONS** |
| 0 | 0 | 0 | 0 | 0 | **OTHER NONBEARING PARTITIONS** |

# CONSTRUCTION TYPES

## NATIONAL BUILDING CODE OF CANADA

This section summarizes the fire-resistance rating and construction requirements for Construction Types in the National Building Code of Canada. Once you have determined an appropriate Construction Type for a project, based on the height and area tables on pages 444–471, use this section to relate this information to systems of construction. The table on these two facing pages consolidates and simplifies the fire-resistance requirements for each Construction Type. The pages following this chart define each Construction Type in terms of specific structural systems, materials, and minimum thicknesses of components necessary to meet the required minimum fire-resistance rating. The values in the table below may be modified as follows:

■ **Loadbearing Columns, Walls, and Arches:** In general, loadbearing elements must have a fire-resistance rating not less than that of the floor, mezzanine, or roof supported by those elements. Where such floors, mezzanines, or roofs are required to be noncombustible, the supporting elements must be noncombustible as well.

■ **Exterior Bearing Walls:** In addition to the requirements indicated in the table on these two facing pages, see also the discussion of fire-resistance requirements for exterior walls, page 374, for information regarding protection of exterior walls in close proximity to other buildings.

**NATIONAL BUILDING CODE OF CANADA FIRE-RESISTANCE RATING REQUIREMENTS**

| | **Noncombustible** | | | |
|---|---|---|---|---|
| **CONSTRUCTION TYPE** | **2-Hour (page 380)** | **1-Hour (page 381)** | **¾-Hour (page 381)** | **Unprotected (page 382)** |
| **LOADBEARING COLUMNS, WALLS, AND ARCHES** | Not less than that required for the floor, mezzanine, or roof supported | | | |
| **FLOOR CONSTRUCTION** | 2 | 2 | 1 | 0 |
| **MEZZANINES** | 1 | 1 | 0 | 0 |
| **ROOF CONSTRUCTION** | 0 | 0–1 | 0 | 0 |
| **PARTY WALLS AND FIRE WALLS** | 2–4 | 2–4 | 2–4 | 2–4 |
| **EXIT STAIR, EXIT PASSAGEWAY, AND SHAFT ENCLOSURES** | 2 | 2 | 2-hr connecting 4 stories or more<br>1-hr connecting less than 4 stories | |
| **EXIT ACCESS CORRIDORS (PAGE 269)** | 0–1 | 0–1 | 0–1 | 0–1 |
| **COMMERCIAL TENANT SEPARATIONS** | 0–1 | 0–1 | 0–1 | 0–1 |
| **DWELLING UNIT AND GUEST ROOM SEPARATIONS** | 1¾ | 1¾ | 1¾ | 1¾ |
| **OTHER NONBEARING PARTITIONS** | 0 (noncombustible) | | | |

# CONSTRUCTION TYPES

■ **Heavy Timber Construction:** Heavy Timber Construction is an acceptable substitute for any building where ¾-Hour or Unprotected Combustible Construction is permitted.

■ **Roofs:** In all Construction Types, roof assemblies may remain unprotected when the building is fully sprinklered. When the building is not sprinklered, roofs must be constructed to the same level of fire resistance required for floors. Additionally, any occupied roof must be constructed to the same level of fire resistance as a floor.

■ **Long-Span Roofs:** Long-span roofs over arenas, sports facilities, and other such spaces are not required to have a fire-resistance rating when not less than 6 m (20 ft) above the floor and supporting normal roof loads only.

■ **Heavy Timber Roofs:** Heavy Timber Roof Construction is permitted in fully sprinklered buildings up to two stories in height, of any Construction Type and any area.

■ **Corridor Enclosures:** For more information on enclosure requirements for exits and corridors, see pages 269 and 275.

■ **Substitution of Higher-Rated Construction Types:** Height and area limits define *minimum* levels of fire protection but do not preclude the use of more fire-resistant systems. For example, where the building code permits a building of Unprotected Combustible Construction, any other Construction Type is also permitted. Where 1-Hour Combustible Construction is required, 1-Hour or greater Noncombustible Construction is also permitted.

| **Combustible** | | | | |
|---|---|---|---|---|
| **Heavy Timber (page 382)** | **1-Hour ( page 384)** | **¾-Hour (page 384)** | **Unprotected (page 384)** | **CONSTRUCTION TYPE** |
| Heavy Timber | Not less than that required for the floor, mezzanine, or roof supported | | | **LOADBEARING COLUMNS, WALLS, AND ARCHES** |
| Heavy Timber | 1 | ¾ | 0 | **FLOOR CONSTRUCTION** |
| Heavy Timber | 1 | 0–¾ | 0 | **MEZZANINES** |
| Heavy Timber | 0–1 | 0–¾ | 0 | **ROOF CONSTRUCTION** |
| 2–4 | 2–4 | 2–4 | 2–4 | **PARTY WALLS AND FIRE WALLS** |
| 2-hr connecting 4 stories or more | | | | **EXIT STAIR, EXIT PASSAGEWAY, AND SHAFT ENCLOSURES** |
| 0–1 | 0–1 | 0–1 | 0–1 | **EXIT ACCESS CORRIDORS (PAGE 269)** |
| 0–1 | 0–1 | 0–1 | 0–1 | **COMMERCIAL TENANT SEPARATIONS** |
| 1¾ | 1¾ | 1¾ | 1¾ | **DWELLING UNIT AND GUEST ROOM SEPARATIONS** |
| 0 | 0 | 0 | 0 | **OTHER NONBEARING PARTITIONS** |

## 3-HOUR NONCOMBUSTIBLE CONSTRUCTION

3-Hour Noncombustible Construction requires a fire-resistance rating of 3 hours for columns and bearing walls and 2 hours for floor construction.

■ **Structural Steel** columns, beams, joists, and decking must be protected to these values with applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or fibrous panels (see pages 96–106).

■ **Light Gauge Steel** wall framing can be assumed to achieve a 3-hour fire-resistance rating with the application of three layers of ½-in. (13-mm) Type X Gypsum wallboard to both sides of the framing. Floor framing can achieve a 2-hour rating with two layers of ⅝-in. (16-mm) Type X Gypsum wallboard applied to the underside of framing supporting a concrete deck (see pages 92–95).

■ **Reinforced Concrete** columns must be at least 12 in. (300 mm) in dimension, and loadbearing walls must be at least 6 in. (150 mm) thick. Floor slabs must be at least 5 in. (125 mm) thick. Concrete one-way and two-way joist systems (ribbed slabs and waffle slabs) with slabs thinner than 5 in. (125 mm) between joists require protection with applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or fibrous panels (see pages 107–123).

■ **Posttensioned Concrete** floor slabs must be at least 5 in. (125 mm) thick (see pages 114–123).

■ **Precast Concrete** columns must be at least 12 in. (300 mm) in dimension, and beams must be at least 7 in. (175 mm) wide. Loadbearing wall panels must be at least 6 (150 mm) thick. Solid slabs may not be less than 5 in. (125 mm) thick. Hollow core slabs must be at least 8 in. (200 mm) deep and may be used without a topping. Double and single tees require applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or fibrous panels, unless a concrete topping 3.25 in. (85 mm) thick is poured (see pages 125–135).

■ **Brick Masonry** loadbearing walls must be at least 6 in. (150 mm) thick. Vaults and domes must be at least 8 in. (200 mm) deep, with a rise not less than one-twelfth the span (see pages 80–85).

■ **Concrete Masonry** columns must be at least 12 in. (300 mm) in dimension, and loadbearing walls must be at least 8 in. (200 mm) thick. Depending on the composition and design of the masonry unit, applied plaster or stucco facings may also be required (see pages 86–90).

Fire-resistive requirements for nonloadbearing walls and partitions are summarized on pages 376–379.

## 2-HOUR NONCOMBUSTIBLE CONSTRUCTION

Two-Hour Noncombustible Construction requires a fire-resistance rating of 2 hours for columns, bearing walls, and floor construction.

■ **Structural Steel** columns, beams, joists, and decking must be protected to these values with applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or fibrous panels (see pages 96–106).

■ **Light Gauge Steel** framing can be assumed to achieve a 2-hour fire-resistance rating with the application of two layers of ⅝-in. (16-mm) Type X Gypsum wallboard to both sides of wall framing or to the underside of floor framing supporting a concrete deck (see pages 92–95).

■ **Reinforced Concrete** columns must be at least 10 in. (250 mm) in dimension, and loadbearing walls must be at least 5 in. (125 mm) thick. Floor slabs must be at least 5 in. (125 mm) thick. Concrete one-way and two-way joist systems (ribbed slabs and waffle slabs) with slabs thinner than 5 in. (125 mm) between joists require protection with applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or fibrous panels (see pages 107–123).

■ **Posttensioned Concrete** floor slabs must be at least 5 in. (125 mm) thick (see pages 114–123).

■ **Precast Concrete** columns must be at least 10 in. (250 mm) in dimension, and beams must be at least 7 in. (175 mm) wide. Loadbearing wall panels must be at least 5 in. (120 mm) thick. Solid slabs may not be less than 5 in. (120 mm) thick. Hollow core slabs must be at least 8 in. (200 mm) deep and may be used without a topping. Double and single tees require applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or fibrous panels, unless a concrete topping 3.25 in. (85 mm) thick is poured (see pages 125–135).

■ **Brick Masonry** loadbearing columns must be at least 12 in. (300 mm) in dimension, and walls must be at least 6 in. (150 mm) thick. Vaults and domes must be at least 8 in. (200 mm) deep, with a rise not less than one-twelfth the span (see pages 80–85).

■ **Concrete Masonry** columns must be at least 10 in. (250 mm) in dimension, and loadbearing walls must be at least 8 in. (200 mm) thick. Depending on the composition and design of the masonry unit, applied plaster or stucco facings may also be required (see pages 86–90).

Fire-resistive requirements for nonloadbearing walls and partitions are summarized on pages 376–379.

## 1-HOUR NONCOMBUSTIBLE CONSTRUCTION

One-Hour Noncombustible Construction requires a fire-resistance rating of 1 hour for columns, bearing walls, and floor construction.

■ **Structural Steel** columns, beams, joists, and decking must be protected to these values with applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or fibrous panels (see pages 96–106).

■ **Light Gauge Steel** framing can be assumed to achieve a 1-hour fire-resistance rating with the application of one layer of ⅝-in. (16-mm) Type X Gypsum wallboard to both sides of wall framing or to the underside of floor framing supporting a concrete deck (see pages 92–95).

■ **Reinforced Concrete** columns must be at least 8 in. (200 mm) in dimension, and loadbearing walls must be at least 4 in. (100 mm) thick. Floor slabs must be at least 3.5 in. (90 mm) thick. Concrete one-way and two-way joist systems (ribbed slabs, skip-joist slabs, and waffle slabs) require protection with applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or acoustical panels unless the slab thickness is at least 3.5 in. (90 mm) between joists (see pages 107–123).

■ **Posttensioned Concrete** floor slabs must be at least 3.5 in. (90 mm) thick (see pages 114–123).

■ **Precast Concrete** columns must be at least 10 in. (250 mm) in dimension, and beams must be at least 4 in. (100 mm) wide. Loadbearing wall panels must be at least 3.5 in. (90 mm) thick. Solid slabs may not be less than 3.5 in. (90 mm) thick. Hollow core slabs must be at least 8 in. (200 mm) deep and may be used without a topping. Double and single tees require applied fireproofing materials or an appropriately fire-resistive ceiling of plaster, gypsum board, or acoustical panels unless a concrete topping 1.75 in. (45 mm) thick is poured (see pages 125–135).

■ **Brick Masonry** columns must be at least 8 in. (200 mm) in dimension, and loadbearing walls must be at least 6 in. (150 mm) thick. Vaults and domes must be at least 4 in. (100 mm) deep, with a rise not less than one-twelfth the span (see pages 80–85).

■ **Concrete Masonry** columns must be at least 8 in. (200 mm) in dimension, and loadbearing walls must be at least 8 in. (200 mm) thick. Depending on the composition and design of the masonry unit, applied plaster or stucco facings may also be required (see pages 86–90).

Fire-resistive requirements for nonloadbearing walls and partitions are summarized on pages 376–379.

## ¾-HOUR NONCOMBUSTIBLE CONSTRUCTION

Three-Quarter-Hour Noncombustible Construction requires a fire-resistance rating of 45 minutes for columns, bearing walls, and floors. This Construction Type is unique to the National Building Code of Canada. In practice, it is most commonly applied to lightweight steel framing systems. For preliminary design purposes, the information provided on this page for 1-Hour Noncombustible Construction may be used to achieve this system's required levels of fire resistance.

## UNPROTECTED NONCOMBUSTIBLE CONSTRUCTION

Unprotected Noncombustible Construction has no fire-resistive requirements for its structural elements other than that they be of noncombustible materials. Structural elements may be sized solely on the basis of structural requirements, without the need for applied fireproofing materials.

- For **Structural Steel**, see pages 96–106.
- For **Light Gauge Steel Framing**, see pages 92–95.
- For **Reinforced Concrete**, see pages 107–123.
- For **Posttensioned Concrete**, see pages 114–123.
- For **Precast Concrete**, see pages 125–135.
- For Brick and Concrete **Masonry**, see pages 79–90.

Fire-resistive requirements for nonloadbearing walls and partitions are summarized on pages 376-379.

## ORDINARY CONSTRUCTION

Ordinary Construction is a system with historical roots in early industrial era fire-resistant construction methods. It consists of noncombustible exterior walls and a Wood Light Frame interior structure.

**Exterior Walls** must be noncombustible, with a fire-resistance rating of not less than 2 hours:

- For **Structural Steel**, see pages 96–106.
- For **Light Gauge Steel Framing**, see pages 92–105.
- For **Reinforced Concrete**, see pages 107–123.
- For **Posttensioned Concrete**, see pages 114–123.
- For **Precast Concrete**, see pages 125–135.
- For Brick and Concrete **Masonry**, see pages 79–90.

**Interior Framing** members of wood must meet the requirements listed on the following pages for Wood Light Frame Construction. For 1-Hour Ordinary Construction, use the requirements for 1-Hour Wood Light Frame Construction; for Unprotected Ordinary Construction, use the requirements for Unprotected Wood Light Frame Construction.

## HEAVY TIMBER CONSTRUCTION AND MILL CONSTRUCTION

This system depends for its fire-resistant properties on wood members of sufficient thickness that they are slow to catch fire and burn. Either solid wood or glue-laminated members may be used.

### International Building Code

The International Building Code refers to this construction system as Type IV Heavy Timber Construction. Exterior walls must be of noncombustible materials with not less than a 2-hour fire-resistance rating. Interior wood members must meet the minimum size requirements described below. In this text, the combination of heavy timber interior structure and rated noncombustible exterior walls is referred to as Mill Construction, a name deriving from this system's origins in early industrial era fire-resistant construction methods.

For noncombustible exterior wall construction, refer to the following:

- For **Structural Steel**, see pages 96–103.
- For **Light Gauge Steel Framing**, see pages 92–95.
- For **Reinforced Concrete**, see pages 107–123.
- For **Posttensioned Concrete**, see pages 114–123.
- For **Precast Concrete**, see pages 125–135.
- For Brick and Concrete **Masonry**, see pages 79–90.

### National Building Code of Canada

In the National Building Code of Canada, buildings of Heavy Timber Construction must meet the minimum size requirements for wood members described below. Unlike the International Building Code, this code places no restriction on the combustibility of exterior walls.

In this model code, Heavy Timber Construction is an acceptable substitute for any building where ¾-Hour or less Combustible Construction is permitted. In addition, in fully sprinklered one- and two-story buildings, heavy timber roofs and their supports are permitted with any Construction Type.

### Minimum Dimensions for Wood Members

Use the following minimum dimensions for wood members for the preliminary design of Heavy Timber and Mill Construction buildings in either code:

- **Solid Wood Columns:** In both model codes, solid wood columns supporting floor loads must be at least 8 × 8 in nominal dimensions (7½ × 7½ in. or 191 × 191 mm actual size). Columns supporting roof loads only must be not less than nominal 6 × 8 (5½ × 7½ in. or 140 × 191 mm).

■ **Glue-Laminated Wood Columns:** In the International Building Code, glue-laminated wood columns supporting floor loads must be at least 6¾ × 8¼ in. (171 × 210 mm) actual size, and supporting roof loads only must be at least 5 × 8¼ in. (127 × 210 mm). In the National Building Code of Canada, columns supporting floors and roofs must be at least 175 × 190 mm (6⅞ × 7½ in.) actual size, and supporting roofs only, at least 130 × 190 mm (5⅛ × 7½ in.).

■ **Solid Wood Beams and Girders:** In both model codes, solid wood beams and girders supporting floor loads must be at least 6 × 10 nominal dimensions (5½ × 9½ in. or 140 × 241 mm actual size), and supporting roof loads only must be at least nominal 4 × 6 (3½ × 5½ in. or 89 × 140 mm). The National Building Code of Canada also permits solid wood beams and girders supporting floors and roofs to have a minimum actual size of 191 × 191 mm (7½ × 7½ in.). In some circumstances, the International Building Code permits solid wood members supporting roof loads only to be as small as nominal 3 in. (2½ in. or 64 mm actual size) wide; see the code for details.

■ **Glue-Laminated Wood Beams and Girders:** In the International Building Code, glue-laminated wood beams and girders supporting floor loads must be at least 5 × 10½ in. (127 × 267 mm) actual size, and supporting roof loads only must be at least 3 × 6⅞ in. (76 × 175 mm). In the National Building Code of Canada, such beams and girders supporting floors and roofs must be not less than 130 × 228 mm (5⅛ × 9 in.) or 175 × 190 mm (6⅞ × 7½ in.) actual size, and supporting roofs only must be at least 80 × 152 mm (3⅛ × 6 in.).

■ **Trusses Made of Solid Wood Members:** In the International Building Code, trusses supporting floor loads must be made of solid wood members no smaller than 8 × 8 nominal dimensions (7½ × 7½ in. or 191 × 191 mm actual size). Roof trusses must be made of members no smaller than nominal 4 × 6 (3½ × 5½ in. or 89 × 140 mm). When trusses are composed of paired solid wood members and the space between members is blocked or covered, individual members may be as little as nominal 3 in. (2½ in. or 64 mm actual size) wide. In the National Building Code of Canada, minimum sizes for truss members made of solid wood are the same as those required in that code for solid wood beams and girders.

■ **Trusses Made of Glue-Laminated Wood Members:** In the International Building Code, trusses supporting floor loads must be made of glue-laminated wood members no smaller than 6¾ × 8¼ in. (171 × 210 mm) actual size. Roof trusses must be made of glue-laminated wood members no smaller than 3 × 6⅞ in. (76 × 175 mm). In the National Building Code of Canada, minimum sizes for truss members made of glue-laminated wood are the same as those required in that code for glue-laminated wood beams and girders.

■ **Glue-Laminated Wood Arches:** In the International Building Code, glue-laminated wood arches supporting floor loads must be no smaller than 6¾ × 8¼ in. (171 × 210 mm) actual size. Arches supporting roof loads only and springing from the floor level must be no smaller than 5 × 8¼ in. (127 × 210 mm) for the lower half and no smaller than 5 × 6 in. (127 × 152 mm) for the upper half. Arches supporting roof loads only and springing from the tops of walls must be not less than 3 × 6⅞ in. (76 × 175 mm). In the National Building Code of Canada, minimum sizes for glue-laminated arches supporting floor loads are the same as those required in that code for glue-laminated wood beams and girders. Arches supporting roof loads only and springing from the floor level must be no smaller than 130 × 152 mm (5⅛ × 6 in.) actual size, and when springing from the tops of walls, they must be no smaller than 80 × 152 mm (3⅛ × 6 in.).

■ **Floors and Roof Decks:** In both model codes, wood floors must consist of not less than 3 in. nominal dimension (2½ in. or 64 mm actual size) solid or glue-laminated wood structural decking. The decking must be overlaid with either finish wood flooring not less than nominal 1 in. (¾ in. or 19 mm) thick or plywood or other wood panels not less than ½ in. (13 mm) thick. Wood roofs must consist of solid or glue-laminated wood structural decking not less than nominal 2 in. (1½ in. or 38 mm actual size), or of 1⅛-in. (28 mm) structural wood panels.

See pages 66–77 for structural information on the wood members in Heavy Timber and Mill Construction.

## 1-HOUR WOOD LIGHT FRAME/COMBUSTIBLE CONSTRUCTION

Floors, walls, and roofs of Wood Light Frame/Combustible Construction are framed with wood members not less than 2 in. in nominal thickness (actually 1½ in., or 38 mm). These members are usually spaced at center-to-center distances of either 16 or 24 in. (400 or 600 mm) and covered with any of a variety of sheathing and finish materials.

In 1-Hour Wood Light Frame/Combustible Construction, load-bearing walls and floors must have 1-hour fire-resistance ratings.

■ **Wood Light Framing** can be assumed to achieve a 1-hour fire-resistance rating with the application of one layer of ⅝-in. (16-mm) Type X Gypsum wallboard to both sides of wall framing, or to the underside of floor framing supporting wood or concrete decks (see pages 58–65).

Any noncombustible construction type with a 1-hour or greater fire-resistance rating is also permitted.

## ¾-HOUR WOOD LIGHT FRAME/COMBUSTIBLE CONSTRUCTION

¾-Hour Combustible Construction, unique to the National Building Code of Canada, requires a fire-resistance rating of 45 minutes for combustible floors, columns, and bearing walls. For preliminary design purposes, the information provided on this page for 1-Hour Wood Light Frame/Combustible Construction may be used to achieve this system's required levels of fire resistance. This code also permits Heavy Timber Construction (pages 382–383) as a substitute wherever ¾-Hour Combustible Construction is required.

Any noncombustible construction type with a ¾-hour or greater fire-resistance rating is also permitted.

## UNPROTECTED WOOD LIGHT FRAME/ COMBUSTIBLE CONSTRUCTION

Unprotected Wood Light Frame/Combustible Construction permits construction with any materials, both combustible and noncombustible, without any added fire protection. It is most commonly used with Wood Light Framing (see pages 58–65).

# 2

# HEIGHT AND AREA TABLES

***This chapter allows you to determine the allowable height and area for your building design, depending on the applicable model building code, Occupancies within your building, and the selected Construction Type.***

## HOW TO USE THE TABLES OF HEIGHT AND AREA LIMITATIONS FOR THE INTERNATIONAL BUILDING CODE

**1.** Be sure you are consulting the tables for the proper building code. If you are not sure which code you are working under, see pages 5–6 and 13.

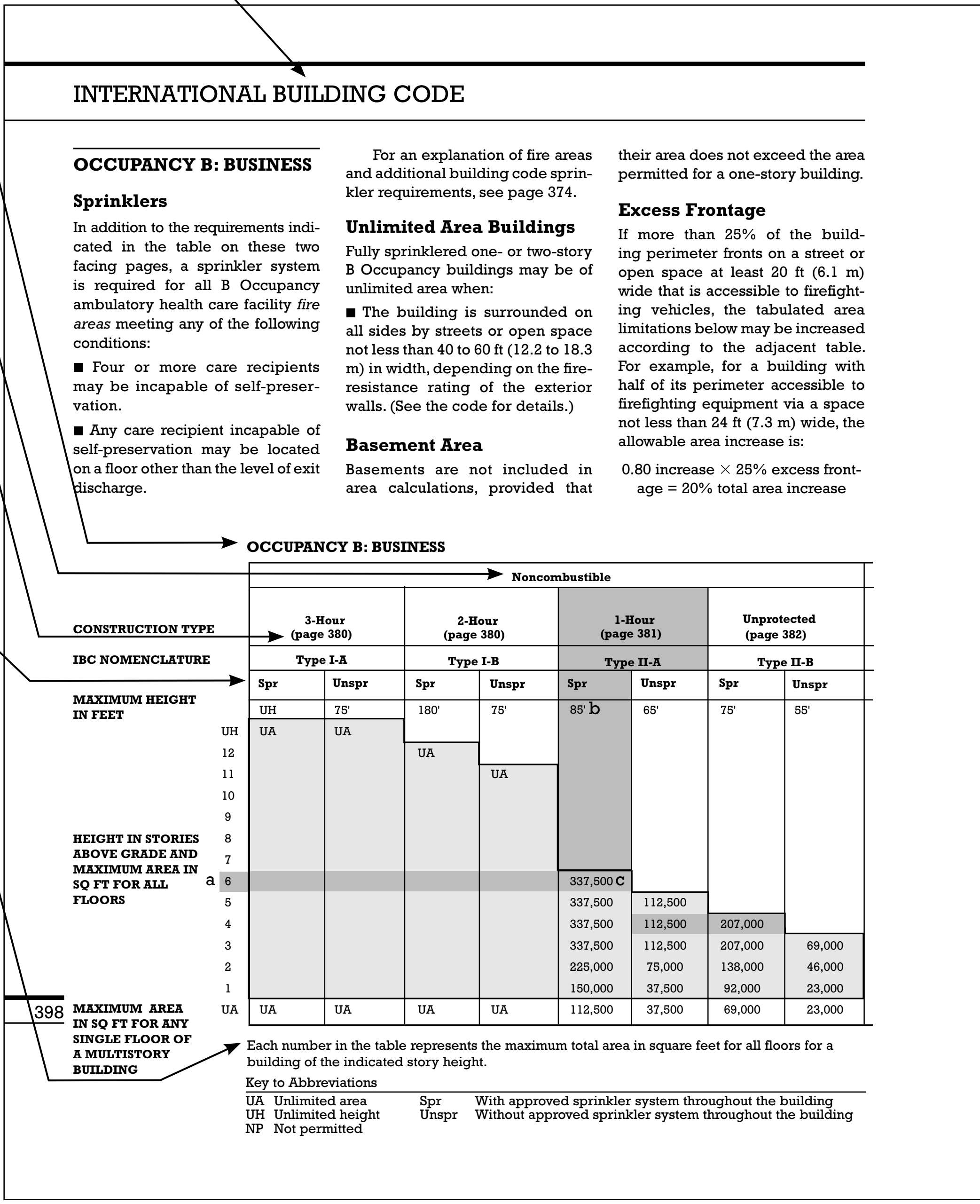
**2.** The Occupancy classification is given at the upper left-hand corner of the table. If you are not sure about the Occupancy into which your building falls, consult the indexes on pages 15–17.

**3.** Noncombustible Construction Types are tabulated on the left-hand page, Combustible Construction Types on the right-hand page.

**4.** Each pair of columns represents one Construction Type. For specific information on the different materials and modes of construction that conform to that Construction Type, follow the page reference given here.

**5.** For each Construction Type, the paired columns tabulate height and area information for both buildings fully sprinklered throughout (Spr) and buildings unsprinklered or only partially sprinklered (Unspr).

**6.** The significance of the floor area numbers in the chart, which varies from one model code to another, is explained at the lower left-hand corner.



INTERNATIONAL BUILDING CODE

**OCCUPANCY B: BUSINESS**

**Sprinklers**

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required for all B Occupancy ambulatory health care facility *fire areas* meeting any of the following conditions:

- Four or more care recipients may be incapable of self-preservation.
- Any care recipient incapable of self-preservation may be located on a floor other than the level of exit discharge.

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

**Unlimited Area Buildings**

Fully sprinklered one- or two-story B Occupancy buildings may be of unlimited area when:

- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

**Basement Area**

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

**Excess Frontage**

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

**OCCUPANCY B: BUSINESS**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | 3-Hour (page 380) | | 2-Hour (page 380) | | 1-Hour (page 381) | | Unprotected (page 382) | |
| **IBC NOMENCLATURE** | | Type I-A | | Type I-B | | Type II-A | | Type II-B | |
| | | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' b | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | UA | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| a | 6 | | | | | 337,500 C | | | |
| | 5 | | | | | 337,500 | 112,500 | | |
| | 4 | | | | | 337,500 | 112,500 | 207,000 | |
| | 3 | | | | | 337,500 | 112,500 | 207,000 | 69,000 |
| | 2 | | | | | 225,000 | 75,000 | 138,000 | 46,000 |
| | 1 | | | | | 150,000 | 37,500 | 92,000 | 23,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | UA | UA | UA | UA | UA | 112,500 | 37,500 | 69,000 | 23,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

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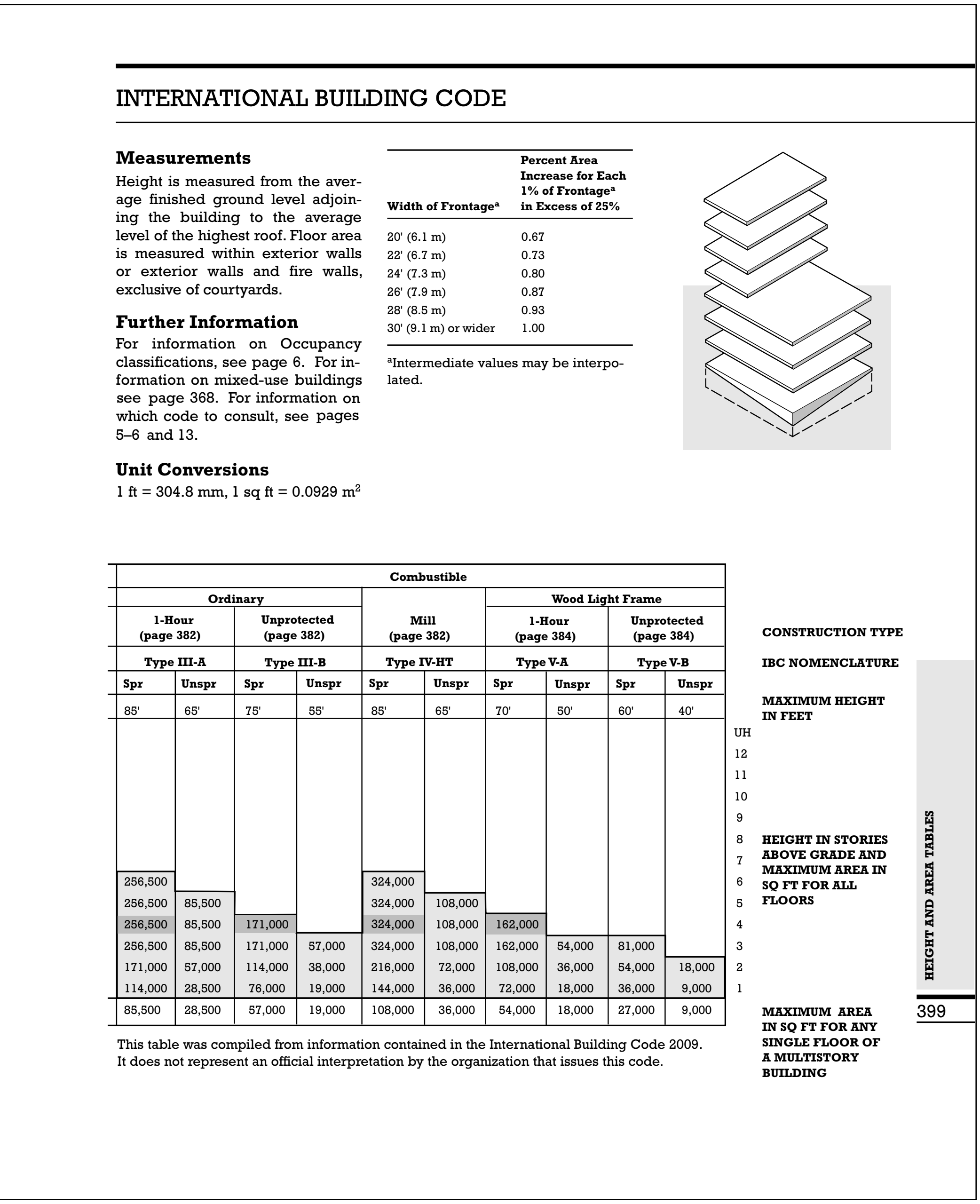
**7.** As an example of the use of this chart, a sprinklered building of Occupancy B, 1-Hour Noncombustible Construction, under the International Building Code, may be no more than (see shaded areas on chart):

a. six stories, or

b. 85 ft tall, whichever is less,

c. with a total floor area (on all floors) no larger than 337,500 sq ft.

**8.** As another example, if we wish to construct a four-story unsprinklered building with 27,500 sq ft per floor, or 110,000 sq ft total area, we must use 1-Hour Noncombustible Construction as a minimum. Looking to the right along the same row of the chart, we see that, with the addition of sprinklers, we could also use any lower construction type except Unprotected Wood Light Frame Construction. We also note that by slightly reducing the total building area to 108,000 sq ft, unsprinklered Mill Construction would be permitted (see the shaded areas on the chart). By following the page references at the heads of these columns, we can determine exactly what each of these Construction Types is and proceed to preliminary configuration and sizing of the structural system we select.



INTERNATIONAL BUILDING CODE

**Measurements**

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

**Further Information**

For information on Occupancy classifications, see page 6. For information on mixed-use buildings see page 368. For information on which code to consult, see pages 5–6 and 13.

**Unit Conversions**

1 ft = 304.8 mm, 1 sq ft = 0.0929 $m^2$

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.

| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| 256,500 | | | | 324,000 | | | | | | 6 | |
| 256,500 | 85,500 | | | 324,000 | 108,000 | | | | | 5 | |
| 256,500 | 85,500 | 171,000 | | 324,000 | 108,000 | 162,000 | | | | 4 | |
| 256,500 | 85,500 | 171,000 | 57,000 | 324,000 | 108,000 | 162,000 | 54,000 | 81,000 | | 3 | |
| 171,000 | 57,000 | 114,000 | 38,000 | 216,000 | 72,000 | 108,000 | 36,000 | 54,000 | 18,000 | 2 | |
| 114,000 | 28,500 | 76,000 | 19,000 | 144,000 | 36,000 | 72,000 | 18,000 | 36,000 | 9,000 | 1 | |
| 85,500 | 28,500 | 57,000 | 19,000 | 108,000 | 36,000 | 54,000 | 18,000 | 27,000 | 9,000 | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

HEIGHT AND AREA TABLES

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The reference tables appearing on the following pages are for preliminary purposes only. They represent the authors' interpretation of certain major provisions of the International Building Code. No official interpretation has been sought from or granted by the International Code Council. For design development work and final preparation of building plans, you must consult the building codes and regulations in effect in your project's locale.

## OCCUPANCY A-1: ASSEMBLY, THEATERS

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required for A-1 Occupancy *fire areas* meeting any of the following conditions:

- When not located on the level of exit discharge
- Exceeding 12,000 sq ft (1115 m$^2$) in area
- With an occupant load of 300 or more
- Containing multitheater complexes

Where required, sprinklers must be provided throughout the floors on which the fire area occurs. When the fire area is not on the level of exit discharge, sprinklers are also required on all floors between it and the exit level, and on the exit level itself.

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

### Unlimited Area Buildings

Fully sprinklered one-story motion picture theater buildings may be of unlimited area when all of the following conditions are met:

- The Construction Type is noncombustible.
- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

Fully sprinklered one-story mixed-occupancy buildings including A-1 Occupancies may be of unlimited area when all of the following conditions are met:

- The Construction Type is other than Wood Light Frame.
- The A-1 Occupancies are separated from other occupancies as required for Separated Occupancies (see page 368).
- The A-1 Occupancy areas do not themselves exceed the area limits in the chart on these two facing pages.
- All exits from A-1 Occupancy areas discharge directly to the building's exterior.
- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-

**OCCUPANCY A-1: ASSEMBLY, THEATERS**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| | UH | UA | UA | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | UA | | | | | |
| | 5 | | | | UA | | | | |
| | 4 | | | | | 139,500 | | | |
| | 3 | | | | | 139,500 | 46,500 | 76,500 | |
| | 2 | | | | | 93,000 | 31,000 | 51,000 | 17,000 |
| | 1 | | | | | 62,000 | 15,500 | 34,000 | 8,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 46,500 | 15,500 | 25,500 | 8,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

resistance rating of the exterior walls. (See the code for details.)

## Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

## Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.

## Measurements

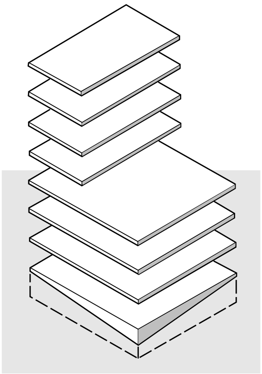
Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | Mill (page 382) | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| 126,000 | | | | 135,000 | | | | | | 4 | |
| 126,000 | 42,000 | 76,500 | | 135,000 | 45,000 | 103,500 | | | | 3 | |
| 84,000 | 28,000 | 51,000 | 17,000 | 90,000 | 30,000 | 69,000 | 23,000 | 33,000 | | 2 | |
| 56,000 | 14,000 | 34,000 | 8,500 | 60,000 | 15,000 | 46,000 | 11,500 | 22,000 | 5,500 | 1 | |
| 42,000 | 14,000 | 25,500 | 8,500 | 45,000 | 15,000 | 34,500 | 11,500 | 16,500 | 5,500 | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY A-2: ASSEMBLY, FOOD AND DRINK ESTABLISHMENTS

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required for A-2 Occupancy *fire areas* meeting any of the following conditions:

- When not located on the level of exit discharge
- Exceeding 5000 sq ft (465 m$^2$) in area
- With an occupant load of 100 or more

Where required, sprinklers must be provided throughout the floors on which the fire area occurs. When the fire area is not on the level of exit discharge, sprinklers are also required on all floors between it and the exit level, and on the exit level itself.

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

### Unlimited Area Buildings

Fully sprinklered one-story mixed-occupancy buildings including A-2 Occupancies may be of unlimited area when all of the following conditions are met:

- The Construction Type is other than Wood Light Frame.
- The A-2 Occupancies are separated from other occupancies as required for Separated Occupancies (see page 368).
- The A-2 Occupancy areas do not themselves exceed the area limits in the chart on these two facing pages.
- All exits from A-2 Occupancy areas discharge directly to the building's exterior.
- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

**OCCUPANCY A-2: ASSEMBLY, FOOD AND DRINK ESTABLISHMENTS**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | UA | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | 139,500 | | | |
| | 3 | | | | | 139,500 | 46,500 | 85,500 | |
| | 2 | | | | | 93,000 | 31,000 | 57,000 | 10,000 |
| | 1 | | | | | 62,000 | 15,500 | 38,000 | 9,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 46,500 | 15,500 | 28,500 | 9,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

## Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

| **Width of Frontage**[a] | **Percent Area Increase for Each 1% of Frontage**[a] **in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

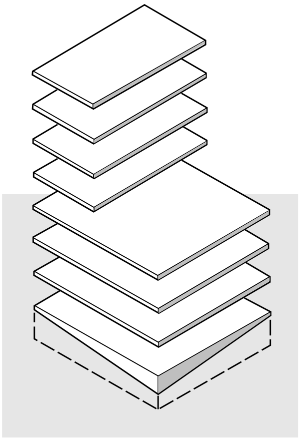
[a]Intermediate values may be interpolated.

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.



## Unit Conversions

1 ft 304.8 mm, 1 sq ft = 0.0929 m$^2$

| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | **Mill (page 382)** | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| 126,000 | | | | 135,000 | | | | | | 4 | |
| 126,000 | 42,000 | 85,500 | | 135,000 | 45,000 | 103,500 | | | | 3 | |
| 84,000 | 28,000 | 57,000 | 19,000 | 90,000 | 30,000 | 69,000 | 23,000 | 36,000 | | 2 | |
| 56,000 | 14,000 | 38,000 | 9,500 | 60,000 | 15,000 | 46,000 | 11,500 | 24,000 | 6,000 | 1 | |
| 42,000 | 14,000 | 28,500 | 9,500 | 45,000 | 15,000 | 34,500 | 11,500 | 18,000 | 6,000 | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY A-3: ASSEMBLY, MISCELLANEOUS

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required for A-3 Occupancy *fire areas* meeting any of the following conditions:

- When not located on the level of exit discharge
- Exceeding 12,000 sq ft (1115 m$^2$) in area
- With an occupant load of 300 or more

Where required, sprinklers must be provided throughout the floors on which the fire area occurs. When the fire area is not on the level of exit discharge, sprinklers are also required on all floors between it and the exit level, and on the exit level itself.

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

### Unlimited Area Buildings

Fully sprinklered one-story A-3 Occupancy buildings used for religious worship, community halls, dance halls, exhibition spaces, gymnasiums, lecture halls, or indoor swimming pools or tennis courts may be of unlimited area when all of the following conditions are met:

- The Construction Type is noncombustible.
- There are no stages or platforms in the building.
- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

Alternatively, the building may be of any Construction Type other than Wood Light Frame if, in addition to the above conditions, the assembly floor is within 21 in. (533 mm) of grade level and all exits are provided with ramps rather than stairs to reach grade.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

**OCCUPANCY A-3: ASSEMBLY, MISCELLANEOUS**

| | | **Noncombustible** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | UA | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | 139,500 | | | |
| | 3 | | | | | 139,500 | 46,500 | 85,500 | |
| | 2 | | | | | 93,000 | 31,000 | 57,000 | 19,000 |
| | 1 | | | | | 62,000 | 15,500 | 38,000 | 9,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 49,500 | 15,500 | 28,500 | 9,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

# INTERNATIONAL BUILDING CODE

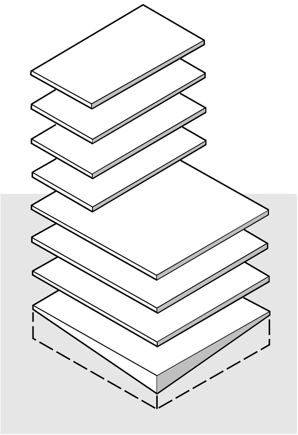
## Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase x 25% excess frontage = 20% total area increase

| **Width of Frontage**[a] | **Percent Area Increase for Each 1% of Frontage**[a] **in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.



## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 $m^2$

| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| 126,000 | | | | 135,000 | | | | | | 4 | |
| 126,000 | 42,000 | 85,500 | | 135,000 | 45,000 | 103,500 | | | | 3 | |
| 84,000 | 28,000 | 57,000 | 19,000 | 90,000 | 30,000 | 69,000 | 23,000 | 36,000 | | 2 | |
| 56,000 | 14,000 | 38,000 | 9,500 | 60,000 | 15,000 | 46,000 | 11,500 | 24,000 | 6,000 | 1 | |
| 42,000 | 14,000 | 28,500 | 9,500 | 45,000 | 15,000 | 34,500 | 11,500 | 18,000 | 6,000 | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY A-4: ASSEMBLY, INDOOR ARENAS

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required for A-4 Occupancy *fire areas* meeting any of the following conditions:

- When not located on the level of exit discharge
- Exceeding 12,000 sq ft (1115 m$^2$) in area
- With an occupant load of 300 or more

Where required, sprinklers must be provided throughout the floors on which the fire area occurs. When the fire area is not on the level of exit discharge, sprinklers are also required on all floors between it and the exit level, and on the exit level itself.

For an explanation of fire areas and additional sprinkler requirements for portions of buildings underground, see page 374.

### Unlimited Area Buildings

Fully sprinklered one-story A-4 Occupancy buildings may be of unlimited area when all of the following conditions are met:

- The Construction Type is other than Light Wood Frame.
- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

Sprinklers need not cover areas occupied by indoor sport activities, provided that the exit doors for those areas lead directly to the outside.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased

**OCCUPANCY A-4: ASSEMBLY, INDOOR ARENAS**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | 3-Hour (page 380) | | 2-Hour (page 380) | | 1-Hour (page 381) | | Unprotected (page 382) | |
| **IBC NOMENCLATURE** | | Type I-A | | Type I-B | | Type II-A | | Type II-B | |
| | | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | UA | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | 139,500 | | | |
| | 3 | | | | | 139,500 | 46,500 | 85,500 | |
| | 2 | | | | | 93,000 | 31,000 | 57,000 | 19,000 |
| | 1 | | | | | 62,000 | 15,500 | 38,000 | 9,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 46,500 | 15,500 | 28,500 | 9,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

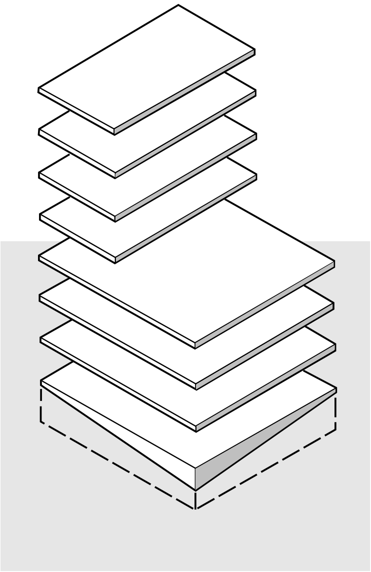
For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 $m^2$

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | **CONSTRUCTION TYPE** |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | **IBC NOMENCLATURE** |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| 126,000 | | | | 135,000 | | | | | | 4 | |
| 126,000 | 42,000 | 85,500 | | 135,000 | 45,000 | 103,500 | | | | 3 | |
| 84,000 | 28,000 | 57,000 | 19,000 | 90,000 | 30,000 | 69,000 | 23,000 | 36,000 | | 2 | |
| 56,000 | 14,000 | 38,000 | 9,500 | 60,000 | 15,000 | 46,000 | 11,500 | 24,000 | 6,000 | 1 | |
| 42,000 | 14,000 | 28,500 | 9,500 | 45,000 | 15,000 | 34,500 | 11,500 | 18,000 | 6,000 | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY A-5: ASSEMBLY, OUTDOOR ARENAS

### Sprinklers

For buildings of this type, sprinklers are required for:

- Concession stands
- Retail areas
- Press boxes
- Other accessory facilities greater than 1000 sq ft (93 $m^2$) in floor area

For additional building code sprinkler requirements, see page 374.

### Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

### Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 $m^2$.

**OCCUPANCY A-5: ASSEMBLY, OUTDOOR ARENAS**

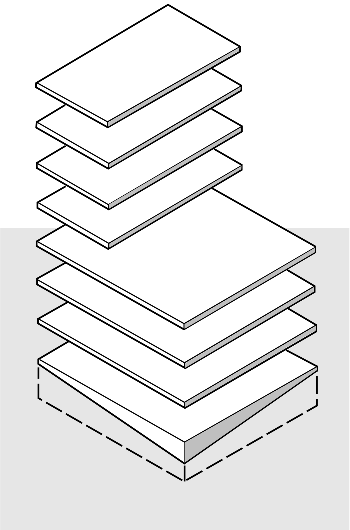
| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | UH | 180' | 160' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | UA | UA | UA | UA | UA | UA |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | | | | | | |
| | 2 | | | | | | | | |
| | 1 | | | | | | | | |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | UA | UA | UA | UA |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

# INTERNATIONAL BUILDING CODE



| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Combustible** | | | | | | | | | | | |
| **Ordinary** | | | | **Mill<br>(page 382)** | | **Wood Light Frame** | | | | | |
| **1-Hour<br>(page 382)** | | **Unprotected<br>(page 382)** | | | | **1-Hour<br>(page 384)** | | **Unprotected<br>(page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | **MAXIMUM HEIGHT IN FEET** |
| UA | UA | UA | UA | UA | UA | UA | UA | UA | UA | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| | | | | | | | | | | 4 | |
| | | | | | | | | | | 3 | |
| | | | | | | | | | | 2 | |
| | | | | | | | | | | 1 | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |
| UA | UA | UA | UA | UA | UA | UA | UA | UA | UA | | |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY B: BUSINESS

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required for all B Occupancy ambulatory health care facility *fire areas* meeting any of the following conditions:

- With four or more care recipients incapable of self-preservation
- With one or more care recipients incapable of self-preservation located on a floor other than the level of exit discharge

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

### Unlimited Area Buildings

Fully sprinklered one- or two-story B Occupancy buildings may be of unlimited area when:

- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

**OCCUPANCY B: BUSINESS**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| | UH | UA | UA | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | UA | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | 337,500 | | | |
| | 5 | | | | | 337,500 | 112,500 | | |
| | 4 | | | | | 337,500 | 112,500 | 207,000 | |
| | 3 | | | | | 337,500 | 112,500 | 207,000 | 69,000 |
| | 2 | | | | | 225,000 | 75,000 | 138,000 | 46,000 |
| | 1 | | | | | 150,000 | 37,500 | 92,000 | 23,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | UA | UA | UA | UA | UA | 112,500 | 37,500 | 69,000 | 23,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

# INTERNATIONAL BUILDING CODE

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

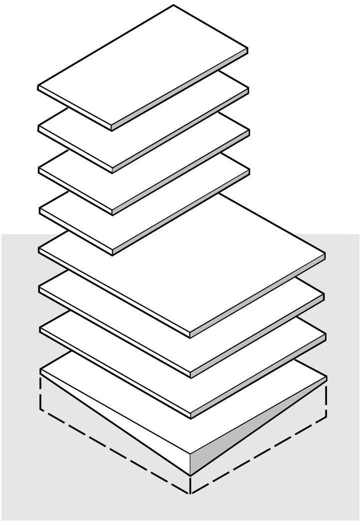
For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | Mill (page 382) | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| 256,500 | | | | 324,000 | | | | | | 6 | |
| 256,500 | 85,500 | | | 324,000 | 108,000 | | | | | 5 | |
| 256,500 | 85,500 | 171,000 | | 324,000 | 108,000 | 162,000 | | | | 4 | |
| 256,500 | 85,500 | 171,000 | 57,000 | 324,000 | 108,000 | 162,000 | 54,000 | 81,000 | | 3 | |
| 171,000 | 57,000 | 114,000 | 38,000 | 216,000 | 72,000 | 108,000 | 36,000 | 54,000 | 18,000 | 2 | |
| 114,000 | 28,500 | 76,000 | 19,000 | 144,000 | 36,000 | 72,000 | 18,000 | 36,000 | 9,000 | 1 | |
| 85,500 | 28,500 | 57,000 | 19,000 | 108,000 | 36,000 | 54,000 | 18,000 | 27,000 | 9,000 | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY E: EDUCATIONAL

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required for all E Occupancy *fire areas* meeting any of the following conditions:

- Exceeding 12,000 sq ft (1115 m$^2$) in area
- Located below the level of exit discharge (below grade), unless every classroom in the building has at least one exit door leading directly to the exterior at grade

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

### Unlimited Area Buildings

Fully sprinklered one-story E Occupancy buildings may be of unlimited area when all of the following conditions are met:

- The Construction Type is Noncombustible, 1-Hour Ordinary, or Mill.
- Each classroom has two independent means of egress, at least one of which leads directly to the exterior.
- The building is surrounded on all sides by streets or open space not less than 60 ft (12.2 to 18.3 m) in width.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to

**OCCUPANCY E: EDUCATIONAL**

|  |  | Noncombustible |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** |  | **3-Hour (page 380)** |  | **2-Hour (page 380)** |  | **1-Hour (page 381)** |  | **Unprotected (page 382)** |  |
| **IBC NOMENCLATURE** |  | **Type I-A** |  | **Type I-B** |  | **Type II-A** |  | **Type II-B** |  |
|  |  | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** |  | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA |  |  |  |  |  |  |
|  | 12 |  |  |  |  |  |  |  |  |
|  | 11 |  |  |  |  |  |  |  |  |
|  | 10 |  |  |  |  |  |  |  |  |
|  | 9 |  |  |  |  |  |  |  |  |
|  | 8 |  |  |  |  |  |  |  |  |
|  | 7 |  |  |  |  |  |  |  |  |
|  | 6 |  |  | UA |  |  |  |  |  |
|  | 5 |  |  |  | UA |  |  |  |  |
|  | 4 |  |  |  |  | 238,500 |  |  |  |
|  | 3 |  |  |  |  | 238,500 | 79,500 | 130,500 |  |
|  | 2 |  |  |  |  | 159,000 | 53,000 | 87,000 | 29,000 |
|  | 1 |  |  |  |  | 106,000 | 26,500 | 58,000 | 14,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |  | UA | UA | UA | UA | 79,500 | 26,500 | 43,500 | 14,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

# INTERNATIONAL BUILDING CODE

firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

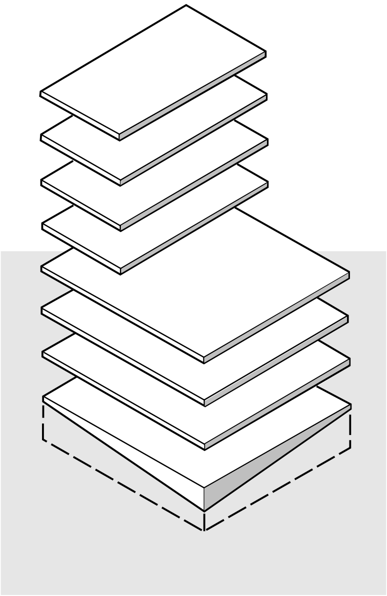
For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

| **Width of Frontage**[a] | **Percent Area Increase for Each 1% of Frontage**[a] **in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a]Intermediate values may be interpolated.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| 211,500 | | | | 229,500 | | | | | | 4 | |
| 211,500 | 70,500 | 130,500 | | 229,500 | 76,500 | | | | | 3 | |
| 141,000 | 47,000 | 87,000 | 29,000 | 153,000 | 51,000 | 111,000 | | 57,000 | | 2 | |
| 94,000 | 23,500 | 58,000 | 14,500 | 102,000 | 25,500 | 74,000 | 18,500 | 9,500 | 9,500 | 1 | |
| 70,500 | 23,500 | 43,500 | 14,500 | 76,500 | 25,500 | 55,500 | 18,500 | 28,500 | 9,500 | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY F-1: FACTORY, MODERATE HAZARD

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required throughout *entire buildings* meeting any of the following conditions:

- Containing an F-1 Occupancy fire area exceeding 12,000 sq ft (1115 $m^2$)
- Containing an F-1 fire area located four or more stories above grade
- Containing multiple F-1 fire areas, including mezzanines, that in total exceed 24,000 sq ft (2230 $m^2$) in area

A sprinkler system is also required for all F-1 Occupancy *fire areas* meeting the following condition:

- Containing woodworking operations that generate or utilize finely divided combustible waste and exceed 2500 sq ft (232 $m^2$) in area

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

### Unlimited Area Buildings

Fully sprinklered one- or two-story F-1 Occupancy buildings may be of unlimited area when:

- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with

**OCCUPANCY F-1: FACTORY, MODERATE HAZARD**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | 225,000 | | | |
| | 4 | | | | | 225,000 | | | |
| | 3 | | UA | | UA | 225,000 | 75,000 | 139,500 | |
| | 2 | | | | | 150,000 | 50,000 | 93,000 | 31,000 |
| | 1 | | | | | 100,000 | 25,000 | 62,000 | 15,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 75,000 | 25,000 | 46,500 | 15,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

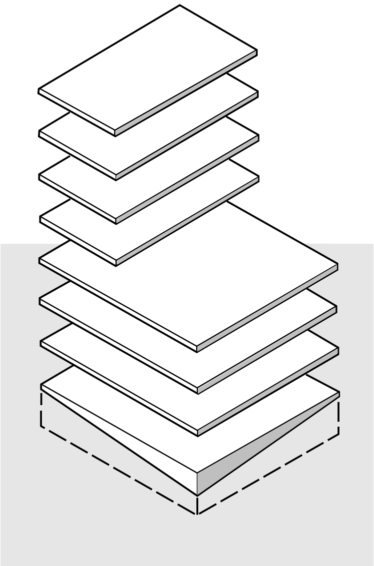
For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 $m^2$

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a]Intermediate values may be interpolated.



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | 301,500 | | | | | | 5 | |
| 171,000 | | | | 301,500 | | | | | | 4 | |
| 171,000 | 57,000 | 108,000 | | 301,500 | 100,500 | 126,000 | | | | 3 | |
| 114,000 | 38,000 | 72,000 | 24,000 | 201,000 | 67,000 | 84,000 | 28,000 | 51,000 | | 2 | |
| 76,000 | 19,000 | 48,000 | 12,000 | 134,000 | 33,500 | 56,000 | 14,000 | 34,000 | 8,500 | 1 | |
| 57,000 | 19,000 | 36,000 | 12,000 | 100,500 | 33,500 | 42,000 | 14,000 | 25,500 | | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY F-2: FACTORY, LOW HAZARD

### Sprinklers

Height and area sprinkler requirements for F-2 Occupancies are incorporated into the table on these two facing pages. For additional sprinkler requirements, see page 374.

### Unlimited Height and Area Buildings

Unsprinklered one-story F-2 Occupancy buildings or fully sprinklered one- or two-story F-2 Occupancy buildings may be of unlimited area when:

- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

Certain fully sprinklered, nonpublic rack storage facilities may be of unlimited height and area. See the code for more information.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

**OCCUPANCY F-2: FACTORY, LOW-HAZARD**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | UA | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | 337,500 | | | |
| | 5 | | | | | 337,500 | 112,500 | | |
| | 4 | | | | | 337,500 | 112,500 | 207,000 | |
| | 3 | | | | | 337,500 | 112,500 | 207,000 | 69,000 |
| | 2 | | | | | 225,000 | 75,000 | 138,000 | 46,000 |
| | 1 | | | | | 150,000 | 37,500 | 92,000 | 23,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 112,500 | 37,500 | 69,000 | 23,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

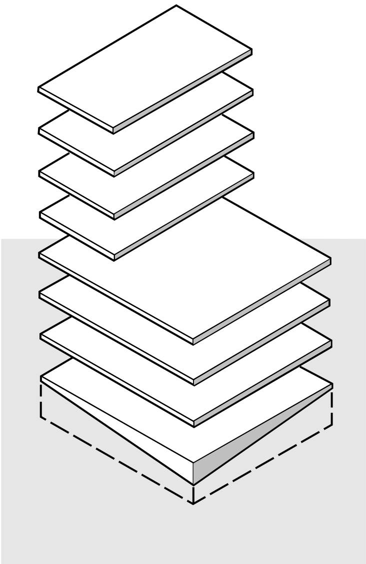
For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a]Intermediate values may be interpolated.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| | Combustible | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ordinary | | | | | | Wood Light Frame | | | | |
| CONSTRUCTION TYPE | 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | |
| IBC NOMENCLATURE | Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | |
| | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | |
| MAXIMUM HEIGHT IN FEET | 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | |
| | | | | | | | | | | | UH |
| | | | | | | | | | | | 12 |
| | | | | | | | | | | | 11 |
| | | | | | | | | | | | 10 |
| | | | | | | | | | | | 9 |
| HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS | | | | | | | | | | | 8 |
| | | | | | | | | | | | 7 |
| | | | | | 454,500 | | | | | | 6 |
| | 256,500 | | | | 454,500 | 151,500 | | | | | 5 |
| | 256,500 | 85,500 | 162,000 | | 454,500 | 151,500 | 189,000 | | | | 4 |
| | 256,500 | 85,500 | 162,000 | 54,000 | 454,500 | 151,500 | 189,000 | 63,000 | 117,000 | | 3 |
| | 171,000 | 57,000 | 108,000 | 36,000 | 303,000 | 101,000 | 126,000 | 42,000 | 78,000 | 26,000 | 2 |
| | 114,000 | 28,500 | 72,000 | 18,000 | 202,000 | 50,500 | 84,000 | 21,000 | 52,000 | 13,000 | 1 |
| MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING | 86,500 | 28,500 | 54,000 | 18,000 | 151,500 | 50,500 | 63,000 | 21,000 | 39,000 | 13,000 | |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY H-1: HIGH-HAZARD, DETONATION

### Special Requirements

All H-1 Occupancy buildings must be used solely for the H-1 use and sprinklered throughout. They may not exceed one story in height or include basements, crawlspaces, or other underfloor areas. They must be set back at least 75 ft (23 m) from adjacent lots. Depending on the quantities and types of hazardous materials stored, the required separation distance from other buildings or public ways may be even greater. See the code for more information.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20 total area increase

### Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

**OCCUPANCY H-1: HIGH-HAZARD, DETONATION**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | | 160' | | 65' | | 55' | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | | | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | | | | | | |
| | 2 | | | | | | | | |
| | 1 | 21,000 | NP | 16,500 | NP | 11,000 | NP | 7,000 | NP |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | | | | | | | | |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

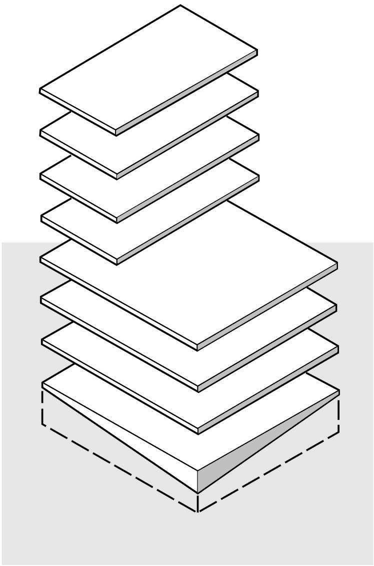
[a] Intermediate values may be interpolated.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 65' | | 55' | | 65' | | 50' | | | | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| | | | | | | | | | | 4 | |
| | | | | | | | | | | 3 | |
| | | | | | | | | | | 2 | |
| 9,500 | NP | 7,000 | NP | 10,500 | NP | 7,500 | NP | NP | NP | 1 | |
| | | | | | | | | | | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY H-2: HIGH-HAZARD, ACCELERATED BURNING

### Special Requirements

All H-2 Occupancy buildings must be sprinklered throughout and, if greater than 1000 sq ft (93 m$^2$) in area, set back at least 30 ft (9.1 m) from adjacent properties. In mixed-occupancy buildings, H-2 Occupancies must be treated as Separated, with 2- to 4-hour fire-resistance rated assemblies between the H-2 and other occupancies involved. Accessory and Nonseparated Occupancy treatments are not permitted (see pages 368–370). Certain H-2 Occupancies of limited area and configuration are permitted to be included in unlimited area F or S Occupancy buildings.

With greater quantities of hazardous material stored, greater separation distances from other buildings and public ways are required. Some H-2 Occupancy buildings are restricted solely to the H-2 use, limited to one story in height, and not permitted to include basements, crawlspaces, or other underfloor areas. See the code for more information.

### Basement Area

Basements, where permitted, are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

**OCCUPANCY H-2: HIGH-HAZARD, ACCELERATED BURNING**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | | 160' | | 65' | | 75' | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | 63,000 | | | | | | | |
| | 12 | 63,000 | | | | | | | |
| | 11 | 63,000 | | | | | | | |
| | 10 | 63,000 | | | | | | | |
| | 9 | 63,000 | | | | | | | |
| | 8 | 63,000 | | | | | | | |
| | 7 | 63,000 | | | | | | | |
| | 6 | 63,000 | | | | | | | |
| | 5 | 63,000 | | | | | | | |
| | 4 | 63,000 | | | | | | | |
| | 3 | 63,000 | | 49,500 | | | | | |
| | 2 | 42,000 | | 33,000 | | 22,000 | | | |
| | 1 | 21,000 | NP | 16,500 | NP | 11,000 | NP | 7,000 | NP |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | 21,000 | | 16,500 | | 11,000 | | | |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

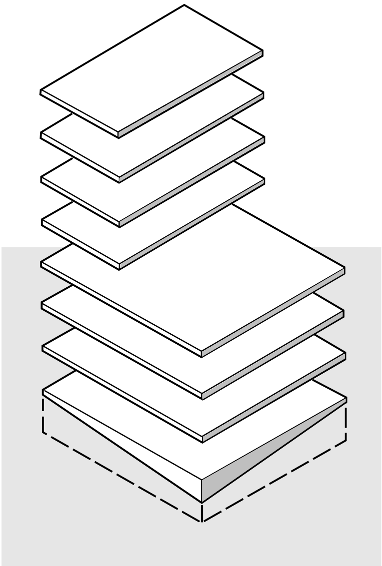
For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$

| **Width of Frontage**[a] | **Percent Area Increase for Each 1% of Frontage**[a] **in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67% |
| 22' (6.7 m) | 0.73% |
| 24' (7.3 m) | 0.80% |
| 26' (7.9 m) | 0.87% |
| 28' (8.5 m) | 0.93% |
| 30' (9.1 m) or wider | 1.00% |

[a]Intermediate values may be interpolated.



| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | | 75' | | 85' | | 70' | | 60' | | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| | | | | | | | | | | 4 | |
| | | | | | | | | | | 3 | |
| 19,000 | | | | 21,000 | | | | | | 2 | |
| 9,500 | NP | 7,000 | NP | 10,500 | NP | 7,500 | NP | 3,000 | NP | 1 | |
| 9,500 | | | | 10,500 | | | | | | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY H-3: HIGH-HAZARD, COMBUSTIBLES

### Special Requirements

All H-3 Occupancy buildings must be sprinklered throughout. In mixed-occupancy buildings, H-3 Occupancies must be treated as Separated, with 1- to 3-hour fire-resistance rated assemblies between the H-3 and other occupancies involved. Accessory and Nonseparated Occupancy treatments are not permitted (see pages 368–370). Certain H-3 Occupancies of limited area and configuration are permitted to be included in unlimited area F or S Occupancy buildings.

With greater quantities of hazardous material stored, separations of 50 ft (15.2 m) or more from other buildings and public ways are required. Some H-3 Occupancy buildings are restricted solely to the H-3 use, limited to one story in height, and not permitted to include basements, crawlspaces, or other underfloor areas. See the code for more information.

### Basement Area

Basements, where permitted, are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

**OCCUPANCY H-3: HIGH-HAZARD, COMBUSTIBLES**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | | 160' | | 65' | | 55' | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | 180,000 | | | | | |
| | 5 | | | 180,000 | | | | | |
| | 4 | | | 180,000 | | 79,500 | | | |
| | 3 | | | 180,000 | | 79,500 | | | |
| | 2 | | | 120,000 | | 53,000 | | 28,000 | |
| | 1 | | NP | 60,000 | NP | 26,500 | NP | 14,000 | NP |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | | 60,000 | | 26,500 | | 14,000 | |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

| **Width of Frontage**[a] | **Area Increase for Each 1% of Frontage**[a] **in Excess of 25** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.

## Measurements

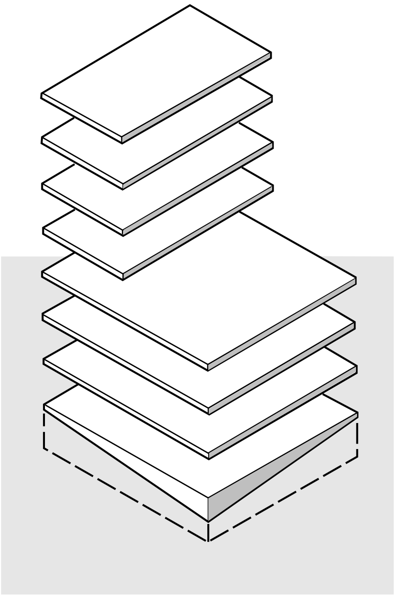
Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$.



| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 65' | | 55' | | 65' | | 50' | | 40' | | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| 52,500 | | | | 76,500 | | | | | | 4 | |
| 52,500 | | | | 76,500 | | | | | | 3 | |
| 35,000 | | 26,000 | | 51,000 | | 20,000 | | | | 2 | |
| 17,500 | NP | 13,000 | NP | 25,500 | NP | 10,000 | NP | 5,000 | NP | 1 | |
| 17,500 | | 13,000 | | 25,500 | | 10,000 | | | | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY H-4: HIGH-HAZARD, CORROSIVES AND TOXICS

### Special Requirements

All H-4 Occupancy buildings must be sprinklered throughout. In mixed-occupancy buildings, H-4 Occupancies must be treated as Separated, with 1- to 3-hour rated assemblies between the H-4 and other Occupancies involved. Accessory and Nonseparated Occupancy treatments are not permitted (see pages 368–370). Certain H-4 Occupancies of limited area and configuration are permitted to be included in unlimited area F or S Occupancy buildings.

### Basement Area

Basements, where permitted, are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

### Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area

**OCCUPANCY H-4: HIGH-HAZARD, CORROSIVES AND TOXICS**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | 3-Hour (page 380) | | 2-Hour (page 380) | | 1-Hour (page 381) | | Unprotected (page 382) | |
| **IBC NOMENCLATURE** | | Type I-A | | Type I-B | | Type II-A | | Type II-B | |
| | | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr |
| **MAXIMUM HEIGHT IN FEET** | | UH | | 180' | | 85' | | 75' | |
| | UH | UA | | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | 8 | | | UA | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | 337,500 | | | |
| | 5 | | | | | 337,500 | | | |
| | 4 | | | | | 337,500 | | 157,500 | |
| | 3 | | | | | 337,500 | | 157,500 | |
| | 2 | | | | | 225,000 | | 105,000 | |
| | 1 | | NP | | NP | 150,000 | NP | 70,000 | NP |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | | UA | | 112,500 | | 52,500 | |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

| **Width of Frontage**[a] | **Percent Area Increase for Each 1% of Frontage**[a] **in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

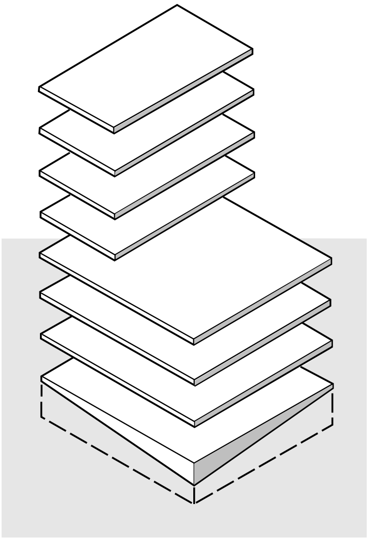
[a] Intermediate values may be interpolated.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | | 75' | | 85' | | 70' | | 60' | | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | 324,000 | | | | | | 6 | |
| 256,500 | | | | 324,000 | | | | | | 5 | |
| 256,500 | | 157,500 | | 324,000 | | 162,000 | | | | 4 | |
| 256,500 | | 157,500 | | 324,000 | | 162,000 | | 58,500 | | 3 | |
| 171,000 | | 105,000 | | 216,000 | | 108,000 | | 39,000 | | 2 | |
| 114,000 | NP | 70,000 | NP | 144,000 | NP | 72,000 | NP | 26,000 | NP | 1 | |
| 85,500 | | 52,500 | | 108,000 | | 54,000 | | 19,500 | | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY H-5: HIGH-HAZARD, HAZARDOUS PRODUCTION MATERIALS

### Special Requirements

All H-5 Occupancy buildings must be sprinklered throughout. In mixed-occupancy buildings, H-5 Occupancies must be treated as Separated, with 1- to 3-hour rated assemblies between the H-5 and other Occupancies involved. Accessory and Nonseparated Occupancy treatments are not permitted (see pages 368–370).

### Basement Area

Basements, where permitted, are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

### Measurements

Height is measured from the average finished ground level adjoining the building to the average

**OCCUPANCY H-5: HIGH-HAZARD, HAZARDOUS PRODUCTION FACILITIES**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | | 160' | | 65' | | 55' | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | | | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | UA | | UA | | | | | |
| | 3 | | | | | 337,500 | | 207,000 | |
| | 2 | | | | | 225,000 | | 138,000 | |
| | 1 | | NP | | NP | 150,000 | NP | 92,000 | NP |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | | UA | | 112,500 | | 69,000 | |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67% |
| 22' (6.7 m) | 0.73% |
| 24' (7.3 m) | 0.80% |
| 26' (7.9 m) | 0.87% |
| 28' (8.5 m) | 0.93% |
| 30' (9.1 m) or wider | 1.00% |

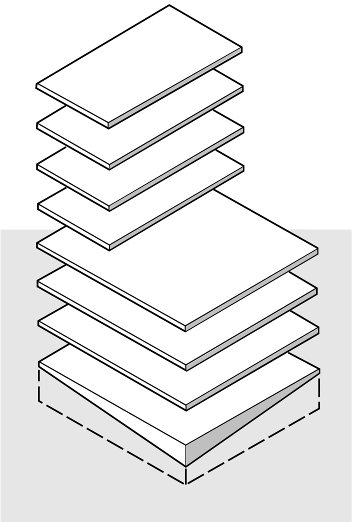
[a] Intermediate values may be interpolated.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 65' | | 55' | | 65' | | 50' | | 40' | | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| | | | | | | | | | | 4 | |
| 256,500 | | 171,000 | | 324,000 | | 162,000 | | | | 3 | |
| 171,000 | | 114,000 | | 216,000 | | 108,000 | | 54,000 | | 2 | |
| 114,000 | NP | 76,000 | NP | 144,000 | NP | 72,000 | NP | 36,000 | NP | 1 | |
| 85,500 | | 57,000 | | 108,000 | | 54,000 | | 27,000 | | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY I-1: INSTITUTIONAL, RESIDENTIAL CARE

### Sprinklers

A sprinkler system is required throughout buildings containing, in whole or in part, an I-1 Occupancy.

In buildings not greater than four stories, less expensive residential class NFPA 13R sprinkler systems are permitted as an alternative to conventional NFPA 13 systems. For buildings with such systems, read the table on these two facing pages from the columns labeled *Residential Spr*. For more information on this sprinkler system type, see page 258.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

### Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area

**OCCUPANCY I-1: INSTITUTIONAL, RESIDENTIAL CARE**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | 495,000 | | | | | |
| | 9 | | | 495,000 | | | | | |
| | 8 | | | 495,000 | | | | | |
| | 7 | | | 495,000 | | | | | |
| | 6 | | | 495,000 | | | | | |
| | 5 | | | 495,000 | | 171,000 | | | |
| | 4 | | UA | 495,000 | 165,000 | 171,000 | 57,000 | 90,000 | |
| | 3 | | | 495,000 | 165,000 | 171,000 | 57,000 | 90,000 | 30,000 |
| | 2 | | | 330,000 | 110,000 | 114,000 | 38,000 | 60,000 | 20,000 |
| | 1 | | | 220,000 | 55,000 | 76,000 | 19,000 | 40,000 | 10,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | 165,000 | 55,000 | 57,000 | 19,000 | 30,000 | 10,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

[a] Residential class sprinkler system NFPA 13R.

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67% |
| 22' (6.7 m) | 0.73% |
| 24' (7.3 m) | 0.80% |
| 26' (7.9 m) | 0.87% |
| 28' (8.5 m) | 0.93% |
| 30' (9.1 m) or wider | 1.00% |

[a] Intermediate values may be interpolated.

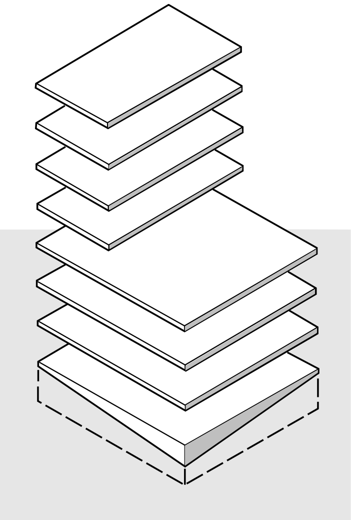
is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| 148,500 | | | | 162,000 | | | | | | 5 | |
| 148,500 | 49,500 | 90,000 | | 162,000 | 54,000 | 94,500 | | | | 4 | |
| 148,500 | 49,500 | 90,000 | 30,000 | 162,000 | 54,000 | 94,500 | 31,500 | 40,500 | | 3 | |
| 99,000 | 33,000 | 60,000 | 20,000 | 108,000 | 36,000 | 63,000 | 21,000 | 27,000 | 9,000 | 2 | |
| 66,000 | 16,500 | 40,000 | 10,000 | 72,000 | 18,000 | 42,000 | 10,500 | 18,000 | 4,500 | 1 | |
| 49,500 | 16,500 | 30,000 | 10,000 | 54,000 | 18,000 | 31,500 | 10,500 | 13,500 | 4,500 | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

## OCCUPANCY I-2: INSTITUTIONAL, MEDICAL, AND CUSTODIAL CARE

### Special Requirements

A sprinkler system is required throughout buildings containing, in whole or in part, an I-2 Occupancy.

In all I-2 Occupancies, floors with an occupant load greater than 50 or used by patients for sleeping or treatment must be subdivided by smoke barriers into at least two separate refuge areas with independent means of egress (see page 278). See the code for additional requirements.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

### Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area

**OCCUPANCY I-2: INSTITUTIONAL, MEDICAL, AND CUSTODIAL CARE**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | | 180' | | 85' | | 55' | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | UA | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | | | 135,000 | | | |
| | 2 | | | | | 90,000 | | | |
| | 1 | | NP | | NP | 60,000 | NP | 44,000 | NP |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | | UA | | 45,000 | | | |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

| **Width of Frontage[a]** | **Percent Area Increase for Each 1% of Frontage[a] in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.

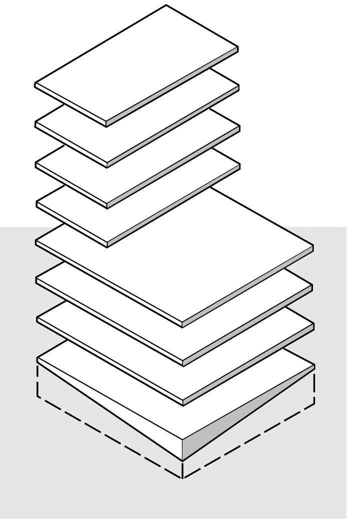
is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 $m^2$



| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 65' | | | | 65' | | 50' | | | | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| | | | | | | | | | | 4 | |
| | | | | | | | | | | 3 | |
| | | | | | | | | | | 2 | |
| 48,000 | NP | NP | NP | 48,000 | NP | 38,000 | NP | NP | NP | 1 | |
| | | | | | | | | | | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY I-3: INSTITUTIONAL, DETENTION AND SECURITY

### Special Requirements

A sprinkler system is required throughout buildings containing, in whole or in part, an I-3 Occupancy.

In all I-3 Occupancies, floors with an occupant load greater than 50 or used by residents for sleeping or treatment must be subdivided by smoke barriers into at least two separate refuge areas with independent means of egress (see page 278). Alternatively, residents may be provided with direct exit access to a public way, separate building, or secured yard or court. See the code for additional requirements.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

**OCCUPANCY I-3: INSTITUTIONAL, DETENTION AND SECURITY**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | | 180' | | 85' | | 75' | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | UA | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | | | 135,000 | | | |
| | 2 | | | | | 90,000 | | 60,000 | |
| | 1 | | NP | | NP | 60,000 | NP | 44,000 | NP |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | | UA | | 45,000 | | 30,000 | |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

| Width of Frontage[a] | Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

*Intermediate values may be interpolated.

## Measurements

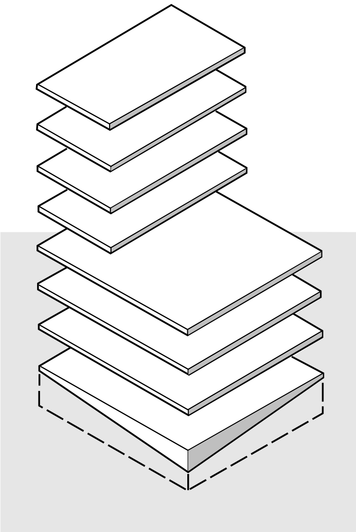
Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 $m^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 85' | | 75' | | 85' | | 70' | | 60' | | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| | | | | | | | | | | 4 | |
| 94,500 | | | | 108,000 | | 67,500 | | | | 3 | |
| 63,000 | | 45,000 | | 72,000 | | 45,000 | | 30,000 | | 2 | |
| 42,000 | NP | 30,000 | NP | 48,000 | NP | 30,000 | NP | 20,000 | NP | 1 | |
| 31,500 | | 22,500 | | 36,000 | | 22,500 | | 15,000 | | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY I-4: INSTITUTIONAL, DAY CARE

### Sprinklers

A sprinkler system is required throughout buildings containing, in whole or in part, an I-4 Occupancy.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67% |
| 22' (6.7 m) | 0.73% |
| 24' (7.3 m) | 0.80% |
| 26' (7.9 m) | 0.87% |
| 28' (8.5 m) | 0.93% |
| 30' (9.1 m) or wider | 1.00% |

[a] Intermediate values may be interpolated

### Measurements

Height is measured from the average finished ground level adjoin-

**OCCUPANCY I-4: INSTITUTIONAL, DAY CARE**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | | 180' | | 85' | | 75' | |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | 544,500 | | | | | |
| | 5 | | | 544,500 | | | | | |
| | 4 | | | 544,500 | | 238,500 | | | |
| | 3 | | | 544,500 | | 238,500 | | 117,000 | |
| | 2 | | | 363,000 | | 159,000 | | 78,000 | |
| | 1 | | NP | 242,000 | NP | 106,000 | NP | 52,000 | NP |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | | 181,500 | | 79,500 | | 39,000 | |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

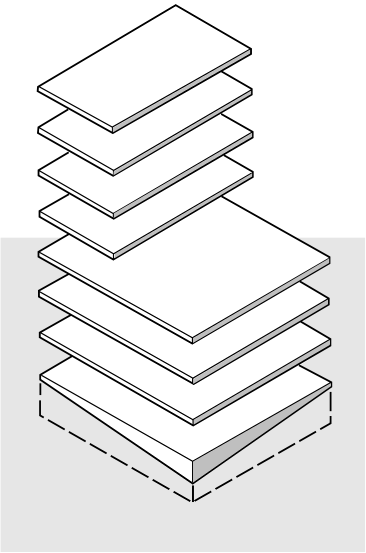
ing the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

### Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | | 75' | | 85' | | 70' | | 60' | | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| 211,500 | | | | 229,500 | | | | | | 4 | |
| 211,500 | | 117,000 | | 229,500 | | | | | | 3 | |
| 141,000 | | 78,000 | | 153,000 | | 111,000 | | 54,000 | | 2 | |
| 94,000 | NP | 52,000 | NP | 102,000 | NP | 74,000 | NP | 36,000 | NP | 1 | |
| 70,500 | | 39,000 | | 76,500 | | 55,500 | | 27,000 | | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY M: MERCANTILE

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required throughout *entire buildings* meeting any of the following conditions:

- Containing an M Occupancy fire area exceeding 12,000 sq ft (1115 m$^2$)
- Containing an M Occupancy fire area located four or more stories above grade
- Containing multiple M Occupancy fire areas, including mezzanines, that in total exceed 24,000 sq ft (2230 m$^2$) in area
- Where upholstered furniture is displayed or sold
- Where merchandise is stored in high-piled or rack storage arrays

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

### Unlimited Area Buildings

Fully sprinklered one- or two-story M Occupancy buildings may be of unlimited area when:

- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

### Covered Mall Buildings

Covered mall buildings, consisting of single buildings enclosing multiple retail, entertainment, and related facilities, are permitted to be of unlimited area, provided that they are fully sprinklered, no more than three stories in height, of any Construction Type except Wood Light Frame, and surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. See the code for additional requirements. In such buildings, tenant spaces must be separated from each other by 1-hour fire-resistance rated partitions. No separation is required between the tenants and the common mall areas.

Covered mall buildings greater than three stories in height must comply with the height and area requirements of the table on these two facing pages.

**OCCUPANCY M: MERCANTILE**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | 193,500 | | | |
| | 4 | | | | | 193,500 | | | |
| | 3 | | UA | | UA | 193,500 | 64,500 | 112,500 | |
| | 2 | | | | | 129,000 | 43,000 | 75,000 | 25,000 |
| | 1 | | | | | 86,000 | 21,500 | 50,000 | 12,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 64,500 | 21,500 | 37,500 | 12,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

# INTERNATIONAL BUILDING CODE

## Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

## Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

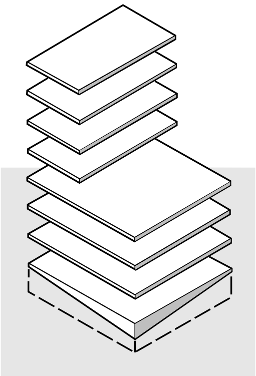
0.80 increase × 25% excess frontage = 20% total area increase

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

| **Width of Frontage**[a] | **Percent Area Increase for Each 1% of Frontage*** **in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

*Intermediate values may be interpolated.



## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 $m^2$

| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| 166,500 | | | | 184,500 | | | | | | 5 | |
| 166,500 | | | | 184,500 | | 126,000 | | | | 4 | |
| 166,500 | 55,500 | 112,500 | | 184,500 | 61,500 | 126,000 | 42,000 | | | 3 | |
| 111,000 | 37,000 | 75,000 | 25,000 | 123,000 | 41,000 | 84,000 | 28,000 | 54,000 | | 2 | |
| 74,000 | 18,500 | 50,000 | 12,500 | 82,000 | 20,500 | 56,000 | 14,000 | 36,000 | 9,000 | 1 | |
| 55,500 | 18,500 | 37,500 | 12,500 | 61,500 | 20,500 | 42,000 | 14,000 | 27,000 | | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY R-1: RESIDENTIAL, HOTELS AND MOTELS

### Sprinklers

A sprinkler system is required throughout buildings containing, in whole or in part, an R-1 Occupancy.

In buildings not greater than four stories and 60 ft (18.3 m) in height, less expensive residential class NFPA 13R sprinkler systems are permitted as an alternative to conventional NFPA 13 systems. For buildings with such systems, read the table on these two facing pages from the columns labeled *Residential Spr*. For more information on this sprinkler system type, see page 258.

### Special Height Exceptions

The code also provides several maximum height exceptions for R-1 Occupancy buildings. When constructed of 1-Hour Ordinary Construction, such buildings may be up to six stories and 75 ft (22.9 m) in height, provided that the floor assembly separating basement areas from the floor at grade level has a fire-resistance rating of at least 3 hours and the building contains continuous vertical 2-hour rated fire walls that subdivide all floors into areas not exceeding 3000 sq ft (279 $m^2$).

Alternatively, when constructed of 1-Hour Noncombustible Construction, an R-1 Occupancy building may be up to nine stories and 100 ft (30.4 m) in height, provided that the floor assembly separating basement areas from the floor at grade level has a fire-resistance rating of at least 1½ hours, exits are separated from the rest of the building by 2-hour rated fire walls, and the building is separated from other buildings and lot lines by a distance of at least 50 ft (15.2 m).

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m)

**OCCUPANCY R-1: RESIDENTIAL, HOTELS AND MOTELS**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 60' | 180' | 60' | 85' | 60' | 75' | 60' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | 216,000 | | 144,000 | |
| | 4 | | UA | | UA | 216,000 | 72,000 | 144,000 | 48,000 |
| | 3 | | | | | 216,000 | 72,000 | 144,000 | 48,000 |
| | 2 | | | | | 144,000 | 48,000 | 96,000 | 32,000 |
| | 1 | | | | | 96,000 | 24,000 | 64,000 | 16,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 72,000 | 24,000 | 48,000 | 16,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

[a]Residential class sprinkler system NFPA 13R.

wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

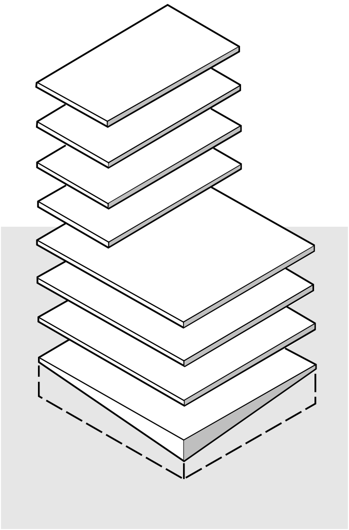
[a]Intermediate values may be interpolated.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | | |
| 85' | 60' | 75' | 60' | 85' | 60' | 70' | 60' | 50' | 60' | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| 216,000 | | 144,000 | | 184,500 | | | | | | 5 | |
| 216,000 | 72,000 | 144,000 | 48,000 | 184,500 | 61,500 | 108,000 | 36,000 | | | 4 | |
| 216000 | 72,000 | 144,000 | 48,000 | 184,500 | 61,500 | 108,000 | 36,000 | 63,000 | 21,000 | 3 | |
| 144,000 | 48,000 | 96,000 | 32,000 | 123,000 | 41,000 | 72,000 | 24,000 | 42,000 | 14,000 | 2 | |
| 96,000 | 24,000 | 64,000 | 16,000 | 82,000 | 20,500 | 48,000 | 12,000 | 28,000 | 7,000 | 1 | |
| 72,000 | 24,000 | 48,000 | 16,000 | 61,500 | 20,500 | 36,000 | 12,000 | 21,000 | 7,000 | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

## OCCUPANCY R-2: RESIDENTIAL, MULTIFAMILY

### Special Requirements

A sprinkler system is required throughout buildings containing, in whole or in part, an R-2 Occupancy.

In buildings not greater than four stories and 60 ft (18.3 m) in height, less expensive residential class NFPA 13R sprinkler systems are permitted as an alternative to conventional NFPA 13 systems. For buildings with such systems, read the table on these two facing pages from the columns labeled *Residential Spr*. For more information on this sprinkler system type, see page 258.

### Special Height Exceptions

The code also provides several maximum height exceptions for R-2 Occupancy buildings. When constructed of 1-Hour Ordinary Construction, such buildings may be up to six stories and 75 ft (22.9 m) in height, provided that the floor assembly separating basement areas from the floor at grade level has a fire-resistance rating of at least 3 hours and the building contains continuous vertical 2-hour rated fire walls that subdivide all floors into areas not exceeding 3000 sq ft (279 m$^2$).

Alternatively, when constructed of 1-Hour Noncombustible Construction, an R-2 Occupancy building may be up to nine stories and 100 ft (30.4 m) in height, provided that the floor assembly separating basement areas from the floor at grade level has a fire-resistance rating of at least 1½ hours, exits are separated from the rest of the building by 2-hour rated fire walls, and the building is separated from other buildings and lot lines by a distance of at least 50 ft (15.2 m).

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m)

**OCCUPANCY R-2: RESIDENTIAL, MULTIFAMILY**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Noncombustible** | | | | | | | |
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 60' | 180' | 60' | 85' | 60' | 75' | 60' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | 216,000 | | 144,000 | |
| | 4 | | UA | | UA | 216,000 | 72,000 | 144,000 | 48,000 |
| | 3 | | | | | 216,000 | 72,000 | 144,000 | 48,000 |
| | 2 | | | | | 144,000 | 48,000 | 96,000 | 32,000 |
| | 1 | | | | | 96,000 | 24,000 | 64,000 | 16,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 72,000 | 24,000 | 48,000 | 16,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

[a] Residential class sprinkler system NFPA 13R.

wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

| Width of Frontage[a] | Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

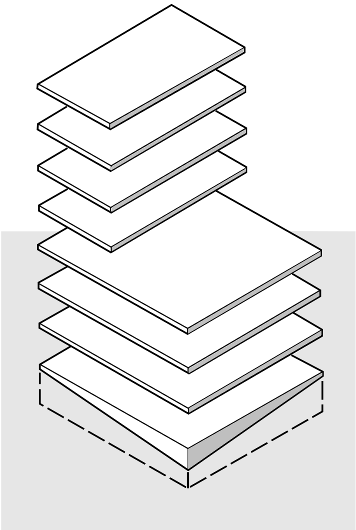
*Intermediate values may be interpolated.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | Mill (page 382) | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | | |
| 85' | 60' | 75' | 60' | 85' | 60' | 70' | 60' | 60' | 60' | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| 216,000 | | 144,000 | | 184,500 | | | | | | 5 | |
| 216,000 | 72,000 | 144,000 | 48,000 | 184,500 | 61,500 | 108,000 | 36,000 | | | 4 | |
| 216,000 | 72,000 | 144,000 | 48,000 | 184,500 | 61,500 | 108,000 | 36,000 | 63,000 | 21,000 | 3 | |
| 144,000 | 48,000 | 96,000 | 32,000 | 123,000 | 41,000 | 72,000 | 24,000 | 42,000 | 14,000 | 2 | |
| 96,000 | 24,000 | 64,000 | 16,000 | 82,000 | 20,500 | 48,000 | 12,000 | 28,000 | 7,000 | 1 | |
| 72,000 | 24,000 | 48,000 | 16,000 | 61,500 | 20,500 | 36,000 | 12,000 | 21,000 | 7,000 | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009.
It does not represent an official interpretation by the organization that issues this code.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

## OCCUPANCY R-3: RESIDENTIAL, MISCELLANEOUS

### International Residential Code

Detached residential one- and two-family dwellings and townhouses are governed by the *International Residential Code*, a separate model code. For buildings of this type, use the following preliminary guidelines:

- All residences must be sprinklered with a light-duty NFPA 13D or equivalent system (see page 258 for more information). Check local code amendments before assuming that this requirement applies to your project.
- Building height is limited to three stories. Area is unlimited.
- Buildings may be of any Construction Type.
- Each dwelling unit must have its own separate means of egress.
- Townhouses must have yards or public ways on at least two sides.
- Townhouse units and dwelling units in two-family buildings must be separated by at least a 1-hour rated wall and floor/ceiling assemblies.
- Every habitable basement and sleeping room must have at least one emergency window or door to the exterior. See page 291.

### International Building Code

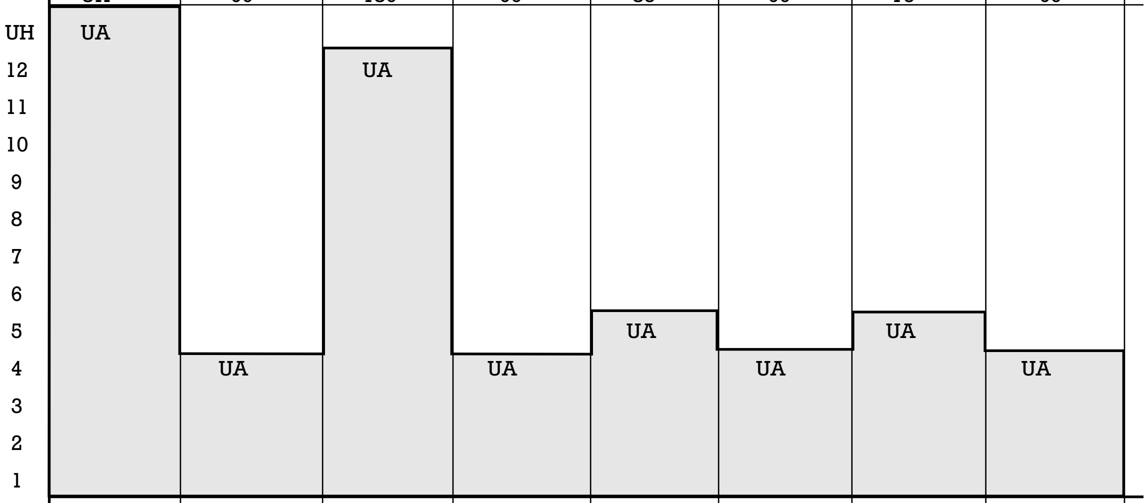
The International Building Code R-3 Occupancy classification governs one- and two-family buildings that exceed the limits of the International Residential Code listed above, as well as congregate living facilities with 16 or fewer occupants and adult or child day care facilities for 5 or fewer persons. For such buildings, use the table on these two facing pages to determine building height and area limitations.

### Sprinklers

A sprinkler system is required throughout buildings containing, in whole or in part, an R-3 Occupancy.

**OCCUPANCY R-3: RESIDENTIAL, MISCELLANEOUS**

| | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | 3-Hour (page 380) | | 2-Hour (page 380) | | 1-Hour (page 381) | | Unprotected (page 382) | |
| **IBC NOMENCLATURE** | Type I-A | | Type I-B | | Type II-A | | Type II-B | |
| | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr |
| **MAXIMUM HEIGHT IN FEET** | UH | 60' | 180' | 60' | 85' | 60' | 75' | 60' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UA | UA | UA | UA | UA | UA | UA | UA |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | UA | UA | UA | UA | UA | UA | UA | UA |



Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

[a]Residential class sprinkler system NFPA 13R.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

In buildings not greater than four stories and 60 ft (18.3 m) in height, residential class NFPA 13R sprinkler systems are permitted (see page 258). For such buildings, read the table on these two facing pages from the columns labeled *Residential Spr*.

## Dwelling Unit Separations

Individual dwelling units in a two-family building must be separated by 1-hour fire-resistance rated wall and floor/ceiling assemblies. Common walls separating adjoining townhouses must be 2-hour rated.

## Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

## Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

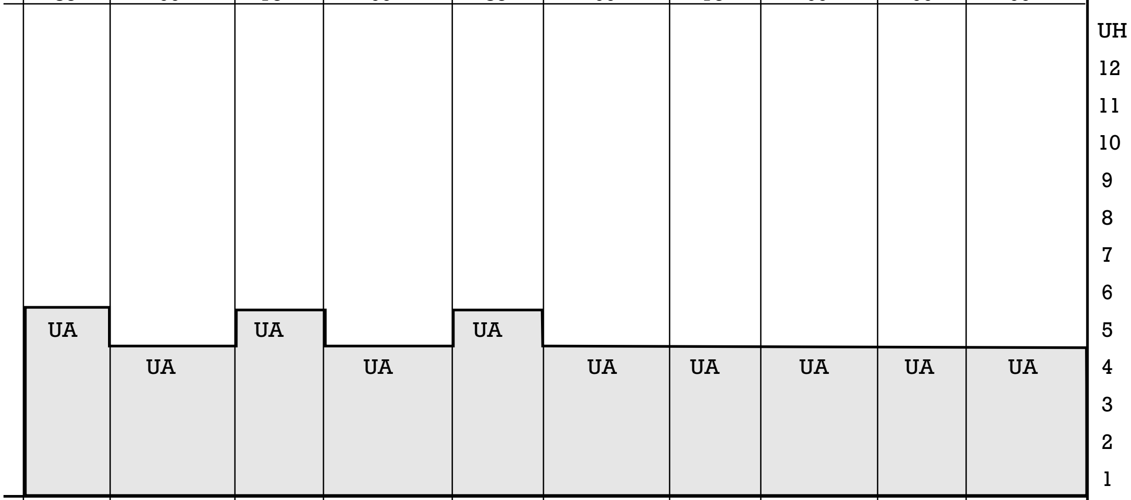
| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

| Combustible | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | IBC NOMENCLATURE |
| Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | |
| 85' | 60' | 75' | 60' | 85' | 60' | 75' | 60' | 60' | 60' | MAXIMUM HEIGHT IN FEET |
| UA | UA | UA | UA | UA | UA | UA | UA | UA | UA | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| UA | UA | UA | UA | UA | UA | UA | UA | UA | UA | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |



This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY R-4: RESIDENTIAL, ASSISTED LIVING

### International Residential Code

Structures housing activities classified by the International Building Code as R-4 Occupancy but meeting the limitations of the International Residential Code may be constructed to the requirements of the International Residential Code. For more information on the limitations of the International Residential Code, see page 430.

### Sprinklers

A sprinkler system is required throughout buildings containing, in whole or in part, an R-4 Occupancy.

In buildings not greater than four stories and 60 ft (18.3 m) in height, less expensive residential class NFPA 13R sprinkler systems are permitted as an alternative to conventional NFPA 13 systems. For buildings with such systems, read the table on these two facing pages from the columns labeled *Residential Spr*. For more information on this sprinkler system type, see page 258.

### Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

### Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equip-

**OCCUPANCY R-4: RESIDENTIAL, ASSISTED LIVING**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Noncombustible** | | | | | | | |
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** | **Spr** | **[a]Residential Spr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 60' | 180' | 60' | 85' | 60' | 75' | 60' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | UA | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | 216,000 | | 144,000 | |
| | 4 | | UA | | UA | 216,000 | 72,000 | 144,000 | 48,000 |
| | 3 | | | | | 216,000 | 72,000 | 144,000 | 48,000 |
| | 2 | | | | | 144,000 | 48,000 | 96,000 | 32,000 |
| | 1 | | | | | 96,000 | 24,000 | 64,000 | 16,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 72,000 | 24,000 | 48,000 | 16,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

[a]Residential class sprinkler system NFPA 13R.

ment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.70 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

*Intermediate values may be interpolated.

## Measurements

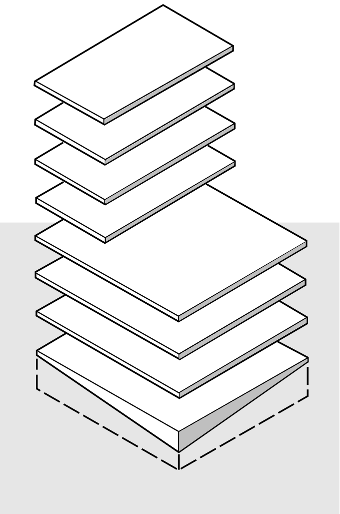
Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | **CONSTRUCTION TYPE** |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | **IBC NOMENCLATURE** |
| Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | Spr | [a]Residential Spr | | |
| 85' | 60' | 75' | 60' | 85' | 60' | 70' | 60' | 60' | 60' | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| 216,000 | | 144,000 | | 184,500 | | | | | | 5 | |
| 216,000 | 72,000 | 144,000 | 48,000 | 184,500 | 61,500 | 108,000 | 36,000 | | | 4 | |
| 216,000 | 72,000 | 144,000 | 48,000 | 184,500 | 61,500 | 108,000 | 36,000 | 63,000 | 21,000 | 3 | |
| 144,000 | 48,000 | 96,000 | 32,000 | 123,000 | 41,000 | 72,000 | 24,000 | 42,000 | 14,000 | 2 | |
| 96,000 | 24,000 | 64,000 | 16,000 | 82,000 | 20,500 | 48,000 | 12,000 | 28,000 | 7,000 | 1 | |
| 72,000 | 24,000 | 48,000 | 16,000 | 61,500 | 20,500 | 36,000 | 12,000 | 21,000 | 7,000 | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

## OCCUPANCY S-1: STORAGE, MODERATE HAZARD

### Sprinklers

In addition to the requirements indicated in the table on these two facing pages, a sprinkler system is required throughout *entire buildings* meeting any of the following conditions:

- Containing an S-1 Occupancy fire area exceeding 12,000 sq ft (1115 $m^2$)
- Containing an S-1 fire area located four or more stories above grade
- Containing multiple S-1 fire areas, including mezzanines, that in total exceed 24,000 sq ft (2230 $m^2$) in area
- Containing an S-1 fire area exceeding 500 sq ft (464 $m^2$) used for the storage of commercial trucks or buses
- Containing storage of vehicular tires exceeding 20,000 cu ft (566 $m^2$) in volume

A sprinkler system is also required throughout buildings containing S-1 Occupancy vehicle repair garages meeting any of the following conditions:

- Buildings with two or more above-ground floors and a fire area greater than 10,000 sq ft (929 $m^2$) in area containing a repair garage
- One-story buildings with a fire area greater than 12,000 sq ft (1115 $m^2$) in area containing a repair garage
- Buildings with repair garages that store serviced vehicles in basements
- Buildings with a fire area greater than 5000 sq ft (464 $m^2$) in area containing a repair garage for commercial trucks or busses

For an explanation of fire areas and additional building code sprinkler requirements, see page 374.

### Unlimited Area Buildings

Fully sprinklered one- or two-story S-1 Occupancy buildings may be of unlimited area when:

- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

**OCCUPANCY S-1: STORAGE, MODERATE HAZARD**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 160' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | | | | | | | |
| | 12 | | | 432,000 | | | | | |
| | 11 | | | 432,000 | | | | | |
| | 10 | | | 432,000 | | | | | |
| | 9 | | | 432,000 | | | | | |
| | 8 | | | 432,000 | | | | | |
| | 7 | | | 432,000 | | | | | |
| | 6 | | | 432,000 | | | | | |
| | 5 | | | 432,000 | | 234,000 | | | |
| | 4 | | | 432,000 | | 234,000 | | | |
| | 3 | | UA | 432,000 | 144,000 | 234,000 | 78,000 | 157,500 | |
| | 2 | | | 288,000 | 96,000 | 156,000 | 52,000 | 105,000 | 35,000 |
| | 1 | | | 192,000 | 48,000 | 104,000 | 26,000 | 70,000 | 17,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | 144,000 | 48,000 | 78,000 | 26,000 | 52,500 | 17,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

## Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

## Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

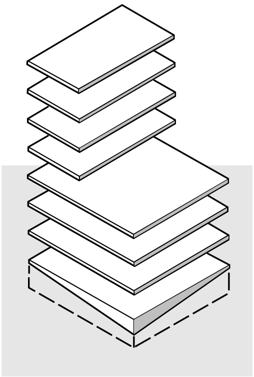
0.80 increase × 25% excess frontage = 20% total area increase

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

| **Width of Frontage**[a] | **Percent Area Increase for Each 1% of Frontage* in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.



## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$

| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | **Mill<br>(page 382)** | | **Wood Light Frame** | | | | | |
| **1-Hour<br>(page 382)** | | **Unprotected<br>(page 382)** | | | | **1-Hour<br>(page 384)** | | **Unprotected<br>(page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | 229,500 | | | | | | 5 | |
| 234,000 | | | | 229,500 | | 126,000 | | | | 4 | |
| 234,000 | 78,000 | 157,500 | | 229,500 | 76,500 | 126,000 | 42,000 | | | 3 | |
| 156,000 | 52,000 | 105,000 | 35,000 | 153,000 | 51,000 | 84,000 | 28,000 | 54,000 | | 2 | |
| 104,000 | 26,000 | 70,000 | 17,500 | 102,000 | 25,500 | 56,000 | 14,000 | 36,000 | 9,000 | 1 | |
| 78,000 | 26,000 | 52,500 | 17,500 | 76,500 | 25,500 | 42,000 | 14,000 | 27,000 | | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY S-2: STORAGE, LOW-HAZARD

### Sprinklers

Height and area sprinkler requirements for S-2 Occupancies are incorporated into the table on these two facing pages. For additional sprinkler requirements, see page 374.

### Unlimited Height and Area Buildings

Unsprinklered one-story S-2 Occupancy buildings or fully sprinklered one- or two-story S-2 Occupancy buildings may be of unlimited area when:

- The building is surrounded on all sides by streets or open space not less than 40 to 60 ft (12.2 to 18.3 m) in width, depending on the fire-resistance rating of the exterior walls. (See the code for details.)

### Vehicle Parking Garages

For enclosed parking garages relying on mechanical ventilation to prevent the accumulation of exhaust gasses, and for naturally ventilated open parking garages combined with other occupancies, use the height and area table on these two facing pages. For buildings containing solely open parking, see Occupancy S-2: Open Parking, on pages 438–439. For private garages and carports, see Occupancy U: Utility, on pages 440–441. For specially permitted mixed-use garage configurations, see page 370.

Open parking garages may be of only Noncombustible or Mill Construction. They may not include vehicle repair work, the dispensing of fuel, or the parking of commercial busses or trucks. For wall opening and building separation distance requirements for open parking garages, see page 345.

Buildings containing, in whole or in part, enclosed parking garages meeting any of the following requirements must be sprinklered throughout:

- The fire area of the garage is greater than 12,000 sq ft (1115 m$^2$).
- The garage is located below any Occupancy other than R-3 Residential, Miscellaneous.
- The fire area of the garage is greater than 5000 sq ft (464 m$^2$) and is used for the storage of commercial trucks and busses.

**OCCUPANCY S-2: STORAGE, LOW-HAZARD**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 75' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | | | | | | |
| | 12 | | | 711,000 | | | | | |
| | 11 | | | 711,000 | 237,000 | | | | |
| | 10 | | | 711,000 | 237,000 | | | | |
| | 9 | | | 711,000 | 237,000 | | | | |
| | 8 | | | 711,000 | 237,000 | | | | |
| | 7 | | | 711,000 | 237,000 | | | | |
| | 6 | | | 711,000 | 237,000 | 351,000 | | | |
| | 5 | | | 711,000 | 237,000 | 351,000 | 117,000 | | |
| | 4 | | | 711,000 | 237,000 | 351,000 | 117,000 | 234,000 | 78,000 |
| | 3 | | | 711,000 | 237,000 | 351,000 | 117,000 | 234,000 | 78,000 |
| | 2 | | | 474,000 | 158,000 | 234,000 | 78,000 | 156,000 | 52,000 |
| | 1 | | | 316,000 | 79,000 | 156,000 | 39,000 | 104,000 | 26,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | 237,000 | 79,000 | 117,000 | 39,000 | 78,000 | 26,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

The minimum clear height within parking garage tiers is 7 ft (2.1 m). Parking is permitted on garage roofs. For more information on the design of parking facilities, see Designing for Parking, beginning on page 327.

## Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

## Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase.

| Width of Frontage[a] | Percent Area Increase for Each 1% of Frontage[a] in Excess of 25% |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$

| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | Mill | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | Mill (page 382) | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | 346,500 | | | | | | 6 | |
| 351,000 | | 234,000 | | 346,500 | 115,500 | 189,000 | | | | 5 | |
| 351,000 | 117,000 | 234,000 | 78,000 | 346,500 | 115,500 | 189,000 | 63,000 | | | 4 | |
| 351,000 | 117,000 | 234,000 | 78,000 | 346,500 | 115,500 | 189,000 | 63,000 | 121,500 | | 3 | |
| 234,000 | 78,000 | 156,000 | 52,000 | 231,000 | 77,000 | 126,000 | 42,000 | 81,000 | 27,000 | 2 | |
| 156,000 | 39,000 | 104,000 | 26,000 | 154,000 | 38,500 | 84,000 | 21,000 | 54,000 | 13,500 | 1 | |
| 117,000 | 39,000 | 78,000 | 26,000 | 115,500 | 38,500 | 63,000 | 21,000 | 40,500 | 13,500 | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY S-2: OPEN PARKING GARAGES

Use the information on these two facing pages for structures containing only single-use, open parking garages. To qualify, two or more sides of the structure must be substantially open to the passage of air and the garage must be used for the parking or storage of private motor vehicles only, excluding commercial trucks and buses. For all other parking structures, see Occupancy S-2: Storage, Low-Hazard, pages 436–437 or, for private garages and carports, Occupancy U: Utility, pages 440–441.

Mixed Occupancies are not permitted, except that up to 1000 sq ft (93 m$^2$) of office space, toilet facilities, and waiting area may be included on the ground level. The minimum vertical clear height within parking garage tiers is 7 ft (2.1 m). Rooftops may be used as parking.

For wall opening and building separation distance requirements for open parking garages, see page 345. For general information on the design of parking facilities, see Designing for Parking, beginning on page 327.

### Height and Area Increases

For garages that are open on three sides, the heights and areas tabulated on these two facing pages may be increased by one floor and 25%, respectively. For garages that are open on four sides, these values may be increased by one floor and 50%. To apply these increases, wall openings must equal at least 50% of the wall area and must be equally distributed along the wall's length.

For garages that are open on four sides, are constructed of 1-Hour or Unprotected Noncombustible Construction, and are not more than 75 ft (22.9 m) in height, floor area is unlimited. Wall opening area must meet the requirements of the previous paragraph, and no point on any floor may be more than 200 ft (61 m) from such openings.

For garages with openings on at least three sides and with less than the maximum permitted number of stories, the combined area of all floors may be increased to as much as that permitted for the maximum height structure. For example,

**OCCUPANCY S-2: OPEN PARKING GARAGES**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | UH | UH | UH | UH | UH | UH | UH |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | | | | | | |
| | 12 | | | UA | UA | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | 500,000 | 500,000 | | |
| | 9 | | | | | 450,000 | 450,000 | | |
| | 8 | | | | | 400,000 | 400,000 | 400,000 | 400,000 |
| | 7 | | | | | 350,000 | 350,000 | 350,000 | 350,000 |
| | 6 | | | | | 300,000 | 300,000 | 300,000 | 300,000 |
| | 5 | | | | | 250,000 | 250,000 | 250,000 | 250,000 |
| | 4 | | | | | 200,000 | 200,000 | 200,000 | 200,000 |
| | 3 | | | | | 150,000 | 150,000 | 150,000 | 150,000 |
| | 2 | | | | | 100,000 | 100,000 | 100,000 | 100,000 |
| | 1 | | | | | 50,000 | 50,000 | 50,000 | 50,000 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | UA | UA | 50,000 | 50,000 | 50,000 | 50,000 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

for a 2-hour Noncombustible open parking garage, 5 floors in height, the tabulated maximum area for all floors is 250,000 sq ft (50,000 sq ft per floor). With this area increase, the area of all floors may be as much as 500,000 sq ft (100,000 sq ft per floor). To apply this increase, at least three sides of the garage must have continuous wall openings, and no point on any floor may be more than 200 ft (61 m) from such an opening. Wall openings must be at least 30 in. (760 mm) in height, extend for at least 80% of the length of the wall, and must face streets at least 30 ft (9.1 m) in width or yards of equal width accessible to firefighting equipment. Standpipes for fire hose connections must also serve each floor.

The allowable number of floors may also be increased by as much as 50% for open parking garages that are fully sprinklered, have limited public access, and use lifts or other mechanical devices to move vehicles to and from the street level. See the code for details.

## Measurements

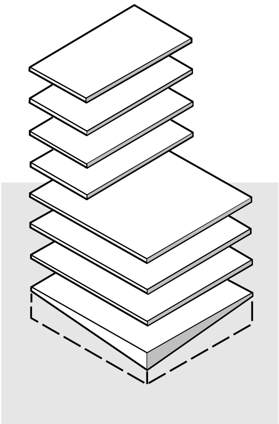
Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$



| Combustible | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ordinary | | | | Mill (page 382) | | Wood Light Frame | | | | | |
| 1-Hour (page 382) | | Unprotected (page 382) | | | | 1-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Type III-A | | Type III-B | | Type IV-HT | | Type V-A | | Type V-B | | | IBC NOMENCLATURE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| | | | | UH | UH | | | | | | MAXIMUM HEIGHT IN FEET |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | | | | | | | 5 | |
| | | | | 200,000 | 200,000 | | | | | 4 | |
| | | | | 150,000 | 150,000 | | | | | 3 | |
| | | | | 100,000 | 100,000 | | | | | 2 | |
| NP | NP | NP | NP | 50,000 | 50,000 | NP | NP | NP | NP | 1 | |
| | | | | 50,000 | 50,000 | | | | | | MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY U: UTILITY

### Sprinklers

Height and area sprinkler requirements for U Occupancies are incorporated into the table on these two facing pages. For additional sprinkler requirements, see page 374.

### Private Garages and Carports

Private garages attached to residences must be separated from adjacent living areas by construction including at least ½-in. (12.5-mm) gypsum wallboard or, where living space is located above the garage, with at least ⅝-in. (16-mm) Type X fire-rated gypsum wallboard. Doors separating living space from private garages must be self-closing, self-latching, not less than 1⅜ in. (35 mm) thick, and made of solid wood or hollow metal, or they may be of other types with at least a 20-minute fire rating. Windows, doors, and other openings between garages and sleeping areas are not permitted. Carports open on at least two sides are not subject to these separation requirements, except that where living space is located above the carport, the floor/ceiling construction must be protected with at least ⅝-in. (16-mm) Type X gypsum wallboard. Garage and carport floor surfaces must be noncombustible or asphalt.

When regulated by the International Residential Code, there are no area limitations on private garages or carports (see page 430 for the building types that apply). When regulated by the International Building Code, Occupancy U private garages and carports are limited to 1000 sq ft (93 m$^2$) in area and one story in height. Alternatively, when used for private vehicle storage and excluding vehicle repair or the dispensing of fuel, such garages may be up to 3000 sq ft (279 m$^2$) in area when the exterior walls are constructed to meet the fire-resistance requirements for the building's primary occupancy. Private garages within mixed-use buildings are considered accessory to the main use, and height and area limitations for building should be determined according to the requirements of the major occupancy.

**OCCUPANCY U: UTILITY**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **3-Hour (page 380)** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **Unprotected (page 382)** | |
| **IBC NOMENCLATURE** | | **Type I-A** | | **Type I-B** | | **Type II-A** | | **Type II-B** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **MAXIMUM HEIGHT IN FEET** | | UH | 75' | 180' | 160' | 85' | 65' | 75' | 55' |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** | UH | UA | UA | | | | | | |
| | 12 | | | | | | | | |
| | 11 | | | | | | | | |
| | 10 | | | | | | | | |
| | 9 | | | | | | | | |
| | 8 | | | | | | | | |
| | 7 | | | | | | | | |
| | 6 | | | 319,500 | | | | | |
| | 5 | | | 319,500 | 106,500 | 171,000 | | | |
| | 4 | | | 319,500 | 106,500 | 171,000 | 57,000 | | |
| | 3 | | | 319,500 | 106,500 | 171,000 | 57,000 | 76,500 | |
| | 2 | | | 213,000 | 71,000 | 114,000 | 38,000 | 51,000 | 17,000 |
| | 1 | | | 142,000 | 35,500 | 76,000 | 19,000 | 34,000 | 8,500 |
| **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** | | UA | UA | 106,500 | 35,500 | 57,000 | 19,000 | 25,500 | 8,500 |

Each number in the table represents the maximum total area in square feet for all floors for a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With approved sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without approved sprinkler system throughout the building |
| NP | Not permitted | | |

# INTERNATIONAL BUILDING CODE

Private garages exceeding Occupancy U area limitations must be classified as Occupancy S-2, or 1-hour rated walls may be used to divide the garage area into multiple separated garages complying with U Occupancy private garage limits.

## Basement Area

Basements are not included in area calculations, provided that their area does not exceed the area permitted for a one-story building.

## Excess Frontage

If more than 25% of the building perimeter fronts on a street or open space at least 20 ft (6.1 m) wide that is accessible to firefighting vehicles, the tabulated area limitations below may be increased according to the adjacent table. For example, for a building with half of its perimeter accessible to firefighting equipment via a space not less than 24 ft (7.3 m) wide, the allowable area increase is:

0.80 increase × 25% excess frontage = 20% total area increase

| **Width of Frontage**[a] | **Percent Area Increase for Each 1% of Frontage**[a] **in Excess of 25%** |
|---|---|
| 20' (6.1 m) | 0.67 |
| 22' (6.7 m) | 0.73 |
| 24' (7.3 m) | 0.80 |
| 26' (7.9 m) | 0.87 |
| 28' (8.5 m) | 0.93 |
| 30' (9.1 m) or wider | 1.00 |

[a] Intermediate values may be interpolated.

## Measurements

Height is measured from the average finished ground level adjoining the building to the average level of the highest roof. Floor area is measured within exterior walls or exterior walls and fire walls, exclusive of courtyards.

## Further Information

For information on Occupancy classifications, see page 6. For information on mixed-use buildings, see page 368. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 ft = 304.8 mm, 1 sq ft = 0.0929 m$^2$

| **Combustible** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ordinary** | | | | | | **Wood Light Frame** | | | | | |
| **1-Hour (page 382)** | | **Unprotected (page 382)** | | **Mill (page 382)** | | **1-Hour (page 384)** | | **Unprotected (page 384)** | | | **CONSTRUCTION TYPE** |
| **Type III-A** | | **Type III-B** | | **Type IV-HT** | | **Type V-A** | | **Type V-B** | | | **IBC NOMENCLATURE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | | |
| 85' | 65' | 75' | 55' | 85' | 65' | 70' | 50' | 60' | 40' | | **MAXIMUM HEIGHT IN FEET** |
| | | | | | | | | | | UH | |
| | | | | | | | | | | 12 | |
| | | | | | | | | | | 11 | |
| | | | | | | | | | | 10 | |
| | | | | | | | | | | 9 | |
| | | | | | | | | | | 8 | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA IN SQ FT FOR ALL FLOORS** |
| | | | | | | | | | | 7 | |
| | | | | | | | | | | 6 | |
| | | | | 162,000 | | | | | | 5 | |
| 126,000 | | | | 162,000 | 54,000 | | | | | 4 | |
| 126,000 | 42,000 | 76,500 | | 162,000 | 54,000 | 81,000 | | | | 3 | |
| 84,000 | 28,000 | 51,000 | 17,000 | 108,000 | 36,000 | 54,000 | 18,000 | 33,000 | | 2 | |
| 56,000 | 14,000 | 34,000 | 8,500 | 72,000 | 18,000 | 36,000 | 9,000 | 22,000 | 5,500 | 1 | |
| 42,000 | 14,000 | 25,500 | 8,500 | 54,000 | 18,000 | 27,000 | 9,000 | 16,500 | | | **MAXIMUM AREA IN SQ FT FOR ANY SINGLE FLOOR OF A MULTISTORY BUILDING** |

This table was compiled from information contained in the International Building Code 2009. It does not represent an official interpretation by the organization that issues this code.

## HOW TO USE THE TABLES OF HEIGHT AND AREA LIMITATIONS FOR THE NATIONAL BUILDING CODE OF CANADA

**1.** Be sure you are consulting the tables for the proper building code. If you are not sure which code you are working under, see pages 5–6 and 13.

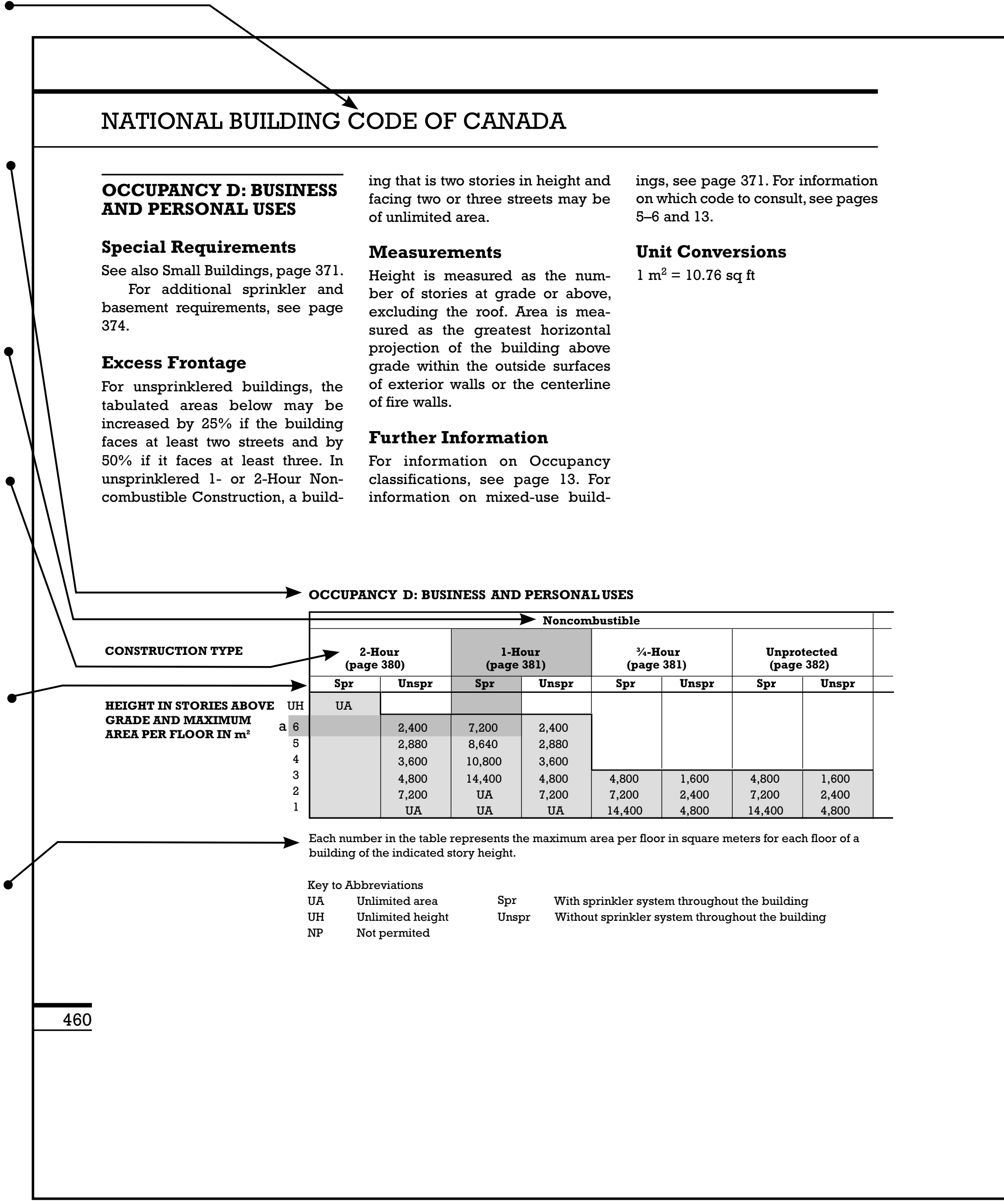
**2.** The Occupancy classification is given at the upper left-hand corner of the table. If you are not sure about the Occupancy into which your building falls, consult the indexes on pages 15–17.

**3.** Noncombustible Construction Types are tabulated on the left-hand page, Combustible Construction Types on the right-hand page.

**4.** Each pair of columns represents one Construction Type. For specific information on the different materials and modes of construction that conform to that Construction Type, follow the page reference given here.

**5.** For each Construction Type, the paired columns tabulate height and area information for both buildings fully sprinklered throughout (Spr) and buildings unsprinklered or only partially sprinklered (Unspr).

**6.** The significance of the floor area numbers in the chart, which varies from one model code to another, is explained at the lower left-hand corner.



NATIONAL BUILDING CODE OF CANADA

**OCCUPANCY D: BUSINESS AND PERSONAL USES**

**Special Requirements**

See also Small Buildings, page 371.

For additional sprinkler and basement requirements, see page 374.

**Excess Frontage**

For unsprinklered buildings, the tabulated areas below may be increased by 25% if the building faces at least two streets and by 50% if it faces at least three. In unsprinklered 1- or 2-Hour Noncombustible Construction, a building that is two stories in height and facing two or three streets may be of unlimited area.

**Measurements**

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

**Further Information**

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

**Unit Conversions**

1 m$^2$ = 10.76 sq ft

**OCCUPANCY D: BUSINESS AND PERSONAL USES**

| | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** UH | UA | | | | | | | |
| a 6 | | 2,400 | 7,200 | 2,400 | | | | |
| 5 | | 2,880 | 8,640 | 2,880 | | | | |
| 4 | | 3,600 | 10,800 | 3,600 | | | | |
| 3 | | 4,800 | 14,400 | 4,800 | 4,800 | 1,600 | 4,800 | 1,600 |
| 2 | | 7,200 | UA | 7,200 | 7,200 | 2,400 | 7,200 | 2,400 |
| 1 | | UA | UA | UA | 14,400 | 4,800 | 14,400 | 4,800 |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

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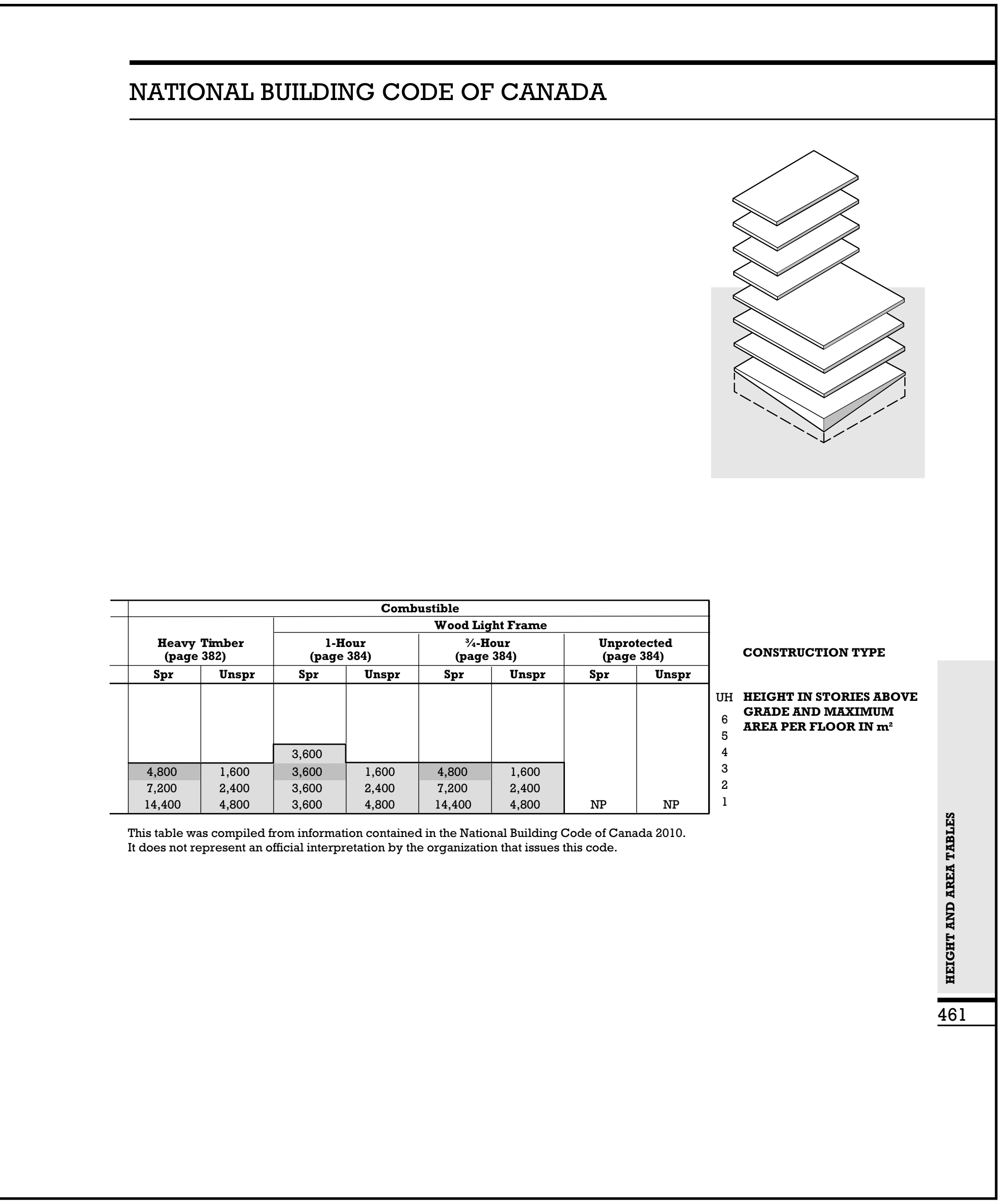
# NATIONAL BUILDING CODE OF CANADA



NATIONAL BUILDING CODE OF CANADA

| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | CONSTRUCTION TYPE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m² |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | 3,600 | | | | | | 4 |
| 4,800 | 1,600 | 3,600 | 1,600 | 4,800 | 1,600 | | | 3 |
| 7,200 | 2,400 | 3,600 | 2,400 | 7,200 | 2,400 | | | 2 |
| 14,400 | 4,800 | 3,600 | 4,800 | 14,400 | 4,800 | NP | NP | 1 |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

**7.** As an example of the use of this chart, a sprinklered building of Occupancy D, 1-Hour Noncombustible Construction, under the National Building Code of Canada, may be no more than (see shaded areas on chart):

**a.** six stories tall

**b.** with no floor larger in area than 7200 m$^2$.

**8.** As another example, if we wish to construct a three-story unsprinklered building of the same Occupancy classification with 3150 m$^2$ per floor, we must use 1-Hour Noncombustible Construction as a minimum. Looking to the right along the same row of the chart, we see that the addition of sprinklers would allow us to use ¾-Hour or Unprotected Noncombustible Construction, Heavy Timber Construction, or 1- or ¾-Hour Combustible Construction (see the shaded areas on the chart). By following the page references at the heads of these columns, we can determine exactly what each of these Construction Types is, and proceed to preliminary configuration and sizing of the structural system we select.

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The reference tables appearing on the following pages are for preliminary design purposes only. They represent the authors' interpretation of certain major provisions of the National Building Code of Canada. No official interpretation has been sought from or granted by the National Research Council of Canada. For design development work and final preparation of building plans, you must consult the building codes and regulations in effect in your project's locale.

## OCCUPANCY A-1: ASSEMBLY, THEATERS

### Special Requirements

When reading the table below, the following requirements apply:

- For buildings of 1-Hour Noncombustible, ¾-Hour Noncombustible, or Heavy Timber Construction, the total occupant load may not exceed 600. Up to 40% of the permitted area may be in a mezzanine or second story containing only nonpublic uses.
- For 1-Hour or ¾-Hour Combustible Construction, the total occupant load may not exceed 300 and the auditorium floor must be within 5 m (16 ft) of grade.

In mixed-occupancy buildings with an assembly seating occupancy greater than 200, the seating area must be separated from adjacent areas on the same floor by walls with fire-resistance ratings of ¾ to 1 hour.

For additional sprinkler and basement requirements, see page 374.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

**OCCUPANCY A-1: ASSEMBLY, THEATERS**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | | | | | | |
| | 2 | | | | | | | | |
| | 1 | | NP | 600[a] | NP | 600[a] | NP | NP | NP |

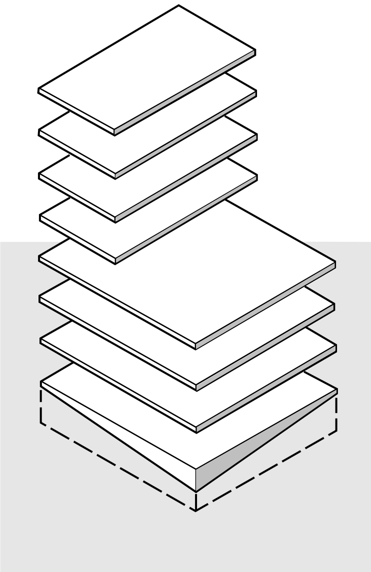
Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height .

[a]See the accompanying text Special Requirements.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | CONSTRUCTION TYPE |
|---|---|---|---|---|---|---|---|---|
| Heavy Timber (page 382) | | Wood Light Frame | | | | | | |
| | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m² |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | | | | | | | 4 |
| | | | | | | | | 3 |
| | | | | | | | | 2 |
| 600[a] | NP | UA[a] | NP | UA[a] | NP | NP | NP | 1 |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY A-2: ASSEMBLY, MISCELLANEOUS

### Special Requirements

When reading the table below, the following requirements apply:

- For single-story buildings of Unprotected Combustible Construction, sprinklered throughout, and without a basement, the building area may be 2400 m$^2$ (25,833 sq ft).
- For buildings of Unprotected Combustible Construction, unsprinklered, and without a basement, the building area may be doubled, provided that the area is divided by 1-hour fire separations into compartments each not exceeding the allowable area indicated in the table.

For additional sprinkler and basement requirements, see page 374.

### Excess Frontage

For unsprinklered buildings, the tabulated areas below may be increased by 25% if the building faces at least two streets and by 50% if it faces at least three.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 m$^2$ = 10.76 sq ft

**OCCUPANCY A-2: ASSEMBLY, MISCELLANEOUS**

| CONSTRUCTION TYPE | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2-Hour (page 380) | | 1-Hour (page 381) | | 3/4-Hour (page 381) | | Unprotected (page 382) | |
| | | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr |
| HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m$^2$ | UH | UA | | | | | | | |
| | 6 | | | UA | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | | | | | | |
| | 2 | | 800 | | 800 | 2,400 | 800 | 2,400 | 800 |
| | 1 | | 1,600 | | 1,600 | 4,800 | 1,600 | 4,800 | 1,600 |

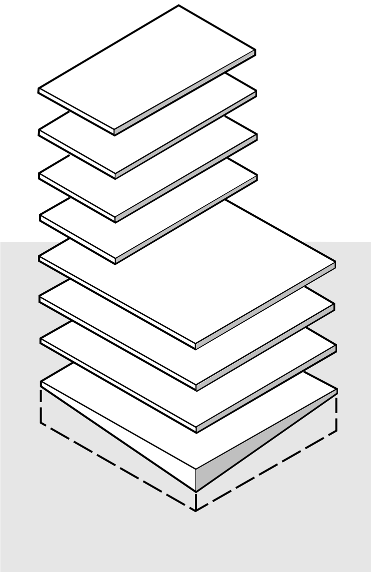
Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

[a]See the accompanying text Special Requirements.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | **CONSTRUCTION TYPE** |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | | | | | | | 4 |
| | | | | | | | | 3 |
| 2,400 | 800 | 2,400 | 800 | 2,400 | 800 | 600 | | 2 |
| 4,800 | 1,600 | 4,800 | 1,600 | 4,800 | 1,600 | 1,200[a] | 400[a] | 1 |

**HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²**

This table was compiled from information contained in the National Building Code of Canada 2010.
It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY A-3: ASSEMBLY, ARENAS

### Special Requirements

When reading the table below, the following requirements apply:

- ■ Unsprinklered buildings of 1-Hour Noncombustible Construction may have roofs and their supporting structure of Heavy Timber Construction.
- ■ Buildings of 1-Hour Noncombustible Construction over 1500 m$^2$ (16,146 sq ft) in area that may be used for exhibition or trade show use must be sprinklered throughout.
- ■ Sprinklered buildings of 1-Hour Noncombustible Construction may have heavy timber arches for support of long-span roofs.

For additional sprinkler and basement requirements, see page 374.

### Excess Frontage

For unsprinklered buildings, the tabulated areas below may be increased by 25% if the building faces at least two streets and by 50% if it faces at least three.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 m$^2$ = 10.76 sq ft

**OCCUPANCY A-3: ASSEMBLY, ARENAS**

| CONSTRUCTION TYPE | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** | UH | UA | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | | | | | | |
| | 2 | | 2,000 | 6,000[a] | 2,000[a] | | | | |
| | 1 | | 4,000 | 12,000[a] | 4,000[a] | 7,200 | 2,400 | 7,200 | 2,400 |

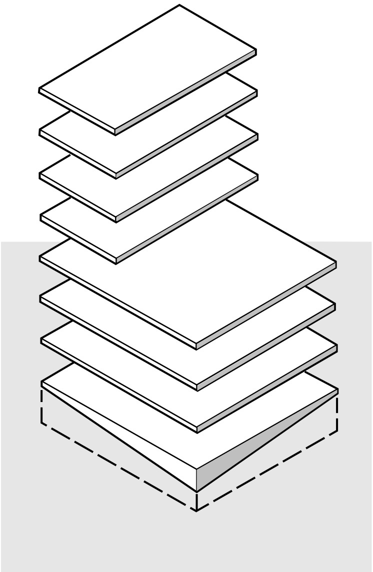
Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

[a] See the accompanying text Special Requirements.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | CONSTRUCTION TYPE |
|---|---|---|---|---|---|---|---|---|
| Heavy Timber (page 382) | | Wood Light Frame | | | | | | |
| | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | | | | | | | 4 |
| | | | | | | | | 3 |
| | | | | | | | | 2 |
| 7,200 | 2,400 | 7,200 | 2,400 | 7,200 | 2,400 | 7,200 | 1,000 | 1 |

This table was compiled from information contained in the National Building Code of Canada 2010.
It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY A-4: ASSEMBLY, OPEN-AIR

### Special Requirements

When reading the table below, the following requirements apply:

- Buildings of Combustible Construction must have an occupant load of less than 1500 and must be separated from adjacent properties or buildings by at least 6 m (20 ft).
- Buildings of Noncombustible Construction may have roofs and their supporting structures made of heavy timber without being subject to the limits above.
- Occupied areas below seating tiers must be sprinklered.

For additional sprinkler and basement requirements, see page 374.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

**OCCUPANCY A-4: ASSEMBLY, OPEN-AIR**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | UA | UA | UA | UA | UA | UA | UA |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | | | | | | |
| | 2 | | | | | | | | |
| | 1 | | | | | | | | |

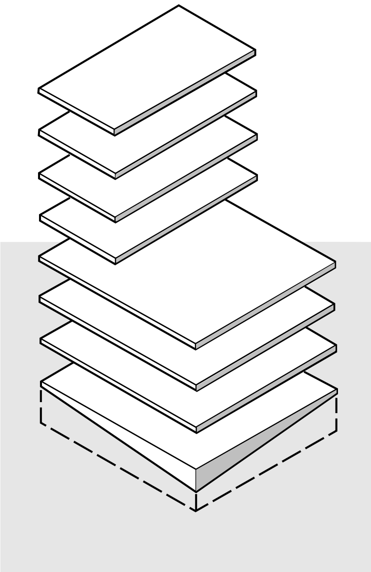
Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

[a] See the accompanying text Special Requirements.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | | CONSTRUCTION TYPE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | | |
| UA[a] | UA[a] | UA[a] | UA[a] | UA[a] | UA[a] | UA[a] | UA[a] | UH | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m² |
| | | | | | | | | 6 | |
| | | | | | | | | 5 | |
| | | | | | | | | 4 | |
| | | | | | | | | 3 | |
| | | | | | | | | 2 | |
| | | | | | | | | 1 | |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY B-1: DETENTION

### Special Requirements

All Occupancy B-1 Detention buildings must be fully sprinklered.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

**OCCUPANCY B-1: DETENTION**

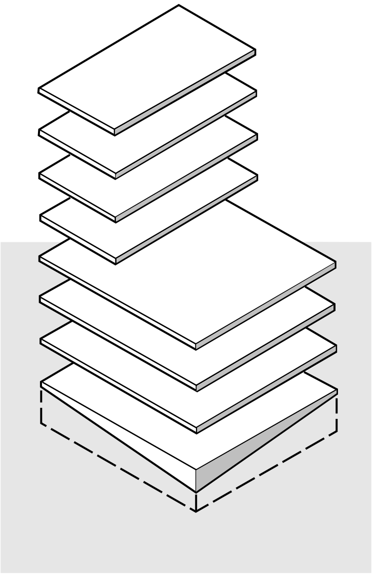
| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | 8,000 | | | | | |
| | 2 | | | 12,000 | | | | | |
| | 1 | | NP | UA | NP | NP | NP | NP | NP |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | | | | | | | 4 |
| | | | | | | | | 3 |
| | | | | | | | | 2 |
| NP | NP | NP | NP | NP | NP | NP | NP | 1 |

**CONSTRUCTION TYPE**

**HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$**

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY B-2: MEDICAL TREATMENT

### Special Requirements

All Occupancy B-2 Medical Treatment buildings must be fully sprinklered.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

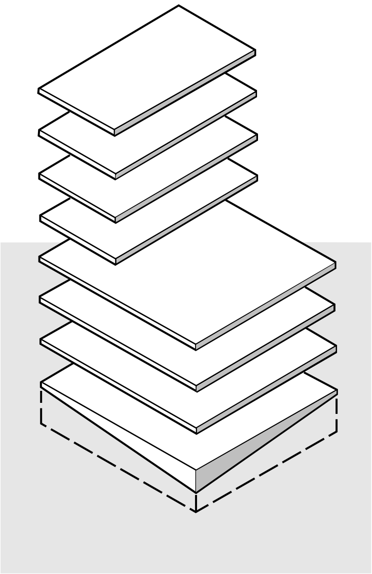
**OCCUPANCY B-2: MEDICAL TREATMENT**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | 8,000 | | | | | |
| | 2 | | | 12,000 | | 1,600 | | | |
| | 1 | | NP | UA | NP | 2,400 | NP | 500 | NP |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | CONSTRUCTION TYPE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | | | | | | | 4 |
| | | | | | | | | 3 |
| 1,600 | | 1,600 | | 1,600 | | | | 2 |
| 2,400 | NP | 2,400 | NP | 2,400 | NP | 500 | NP | 1 |

**HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²**

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY B-3: CARE

### Special Requirements

All Occupancy B-3 Care buildings must be fully sprinklered.

In buildings that are not more than three stories in height and housing not more than 10 occupants, NFPA 13R (residential) sprinkler systems are permitted. In buildings that are not more than three stories in height, with not more than two care suites and not more than five occupants total, NFPA 13D (one- and two-family dwelling) sprinkler systems are permitted. For more information on these sprinkler system types, see page 258.

For other sprinkler and basement requirements, see page 374.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

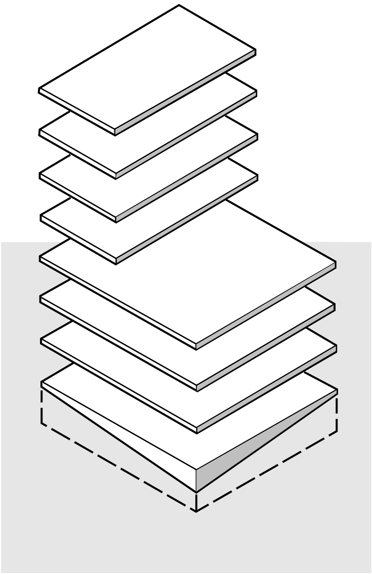
**OCCUPANCY B-3: CARE**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | | | | | | |
| | 3 | | | 8,000 | | | | | |
| | 2 | | | 12,000 | | 1,600 | | | |
| | 1 | | NP | UA | NP | 2,400 | NP | 600 | NP |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | CONSTRUCTION TYPE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m² |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | | | | | | | 4 |
| | | 1,800 | | | | | | 3 |
| 1,600 | | 2,700 | | 1,600 | | | | 2 |
| 2,400 | NP | 5,400 | NP | 2,400 | NP | 600 | NP | 1 |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY C: RESIDENTIAL

### Special Requirements

When reading the table below, the following requirements apply:

- For preliminary design purposes, assume that floors within individual dwelling units must be 1-hour fire-resistance rated and that individual dwelling units must be separated from other areas with 1-hour rated assemblies. See the code for details.
- In buildings of four stories or less, where dwelling units occur only side by side and never one above the other, floors within individual dwelling units may be of Unprotected Construction.

In buildings of Residential Occupancy throughout and that are not more than four stories in height, NFPA 13R (residential) sprinkler systems are permitted in lieu of NFPA 13 (commercial) systems. In buildings that are not more than three stories in height, with not more than two dwelling units, NFPA 13D (one- and two-family dwelling) sprinkler systems are permitted. For more information on these sprinkler system types, see page 258.

See also Small Buildings, page 371.

For additional sprinkler and basement requirements, see page 374.

### Excess Frontage

For unsprinklered buildings, the tabulated areas below may be increased by 25% if the building faces at least two streets and by 50% if it faces at least three streets. In unsprinklered 1- or 2-Hour Noncombustible Construction, a building that is two stories in height and facing two or three streets may be of unlimited area.

**OCCUPANCY C: RESIDENTIAL**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** | UH | UA | | | | | | | |
| | 6 | | | 6,000 | | | | | |
| | 5 | | | 7,200 | | | | | |
| | 4 | | | 9,000 | | | | | |
| | 3 | | 4,000 | 12,000 | 4,000 | 1,800 | 600 | | |
| | 2 | | 6,000 | UA | 6,000 | 2,700 | 900 | | |
| | 1 | | UA | UA | UA | 5,400 | 1,800 | NP | NP |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA

## Measurements

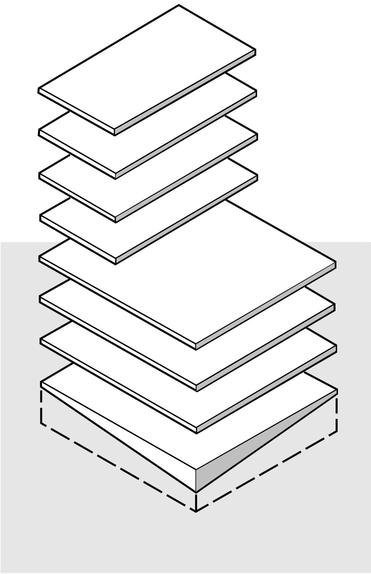
Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

## Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 $m^2$ = 10.76 sq ft



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | CONSTRUCTION TYPE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | 1,800 | | | | | | 4 |
| 1,800 | 600 | 2,400 | 800 | 1,800 | 600 | | | 3 |
| 2,700 | 900 | 3,600 | 1,200 | 2,700 | 900 | | | 2 |
| 5,400 | 1,800 | 7,200 | 2,400 | 5,400 | 1,800 | NP | NP | 1 |

**HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$**

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY D: BUSINESS AND PERSONAL USES

### Special Requirements

See also Small Buildings, page 371.

For additional sprinkler and basement requirements, see page 374.

### Excess Frontage

For unsprinklered buildings, the tabulated areas below may be increased by 25% if the building faces at least two streets and by 50% if it faces at least three. In unsprinklered 1- or 2-Hour Noncombustible Construction, a building that is two stories in height and facing two or three streets may be of unlimited area.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

**OCCUPANCY D: BUSINESS AND PERSONAL USES**

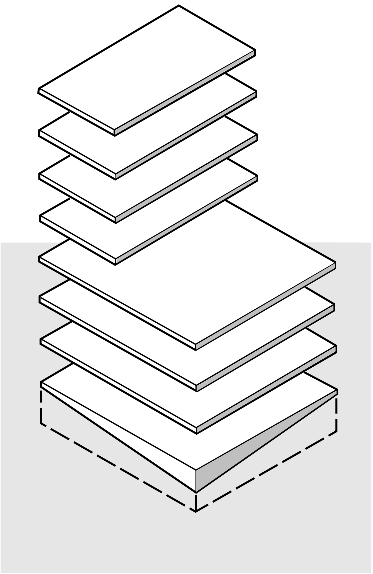
| | | **Noncombustible** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | | | | | | | |
| | 6 | | 2,400 | 7,200 | 2,400 | | | | |
| | 5 | | 2,880 | 8,640 | 2,880 | | | | |
| | 4 | | 3,600 | 10,800 | 3,600 | | | | |
| | 3 | | 4,800 | 14,400 | 4,800 | 4,800 | 1,600 | 4,800 | 1,600 |
| | 2 | | 7,200 | UA | 7,200 | 7,200 | 2,400 | 7,200 | 2,400 |
| | 1 | | UA | UA | UA | 14,400 | 4,800 | 14,400 | 4,800 |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| **Heavy Timber (page 382)** | | **1-Hour (page 384)** | | **¾-Hour (page 384)** | | **Unprotected (page 384)** | | **CONSTRUCTION TYPE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | 3,600 | | | | | | 4 |
| 4,800 | 1,600 | 3,600 | 1,600 | 4,800 | 1,600 | | | 3 |
| 7,200 | 2,400 | 3,600 | 2,400 | 7,200 | 2,400 | | | 2 |
| 14,400 | 4,800 | 3,600 | 4,800 | 14,400 | 4,800 | NP | NP | 1 |

**HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²**

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY E: MERCANTILE

### Special Requirements

For Small Buildings, see page 371.

For additional sprinkler and basement requirements, see page 374.

### Excess Frontage

For unsprinklered buildings, the tabulated areas below may be increased by 25% if the building faces at least two streets and by 50% if it faces at least three.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

**OCCUPANCY E: MERCANTILE**

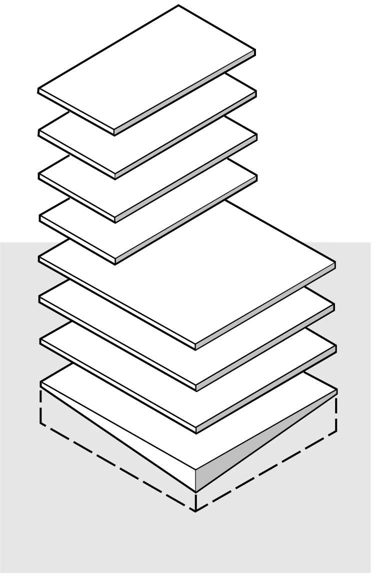
| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | 1,800 | | | | | |
| | 3 | | 800 | 1,800 | 800 | 2,400 | 800 | | |
| | 2 | | 1,200 | 1,800 | 1,200 | 3,600 | 1,200 | | |
| | 1 | | 1,500 | 1,800 | 1,500 | 7,200 | 1,500 | NP | NP |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| **Heavy Timber (page 382)** | | **1-Hour (page 384)** | | **¾-Hour (page 384)** | | **Unprotected (page 384)** | | **CONSTRUCTION TYPE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | 1,800 | | | | | | 4 |
| 2,400 | 800 | 1,800 | 800 | 2,400 | 800 | | | 3 |
| 3,600 | 1,200 | 1,800 | 1,200 | 3,600 | 1,200 | | | 2 |
| 7,200 | 1,500 | 1,800 | 1,500 | 7,200 | 1,500 | NP | NP | 1 |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY F-1: INDUSTRIAL, HIGH-HAZARD

### Special Requirements

Provincial or other local regulations may alter sprinkler requirements for buildings of this occupancy classification.

For additional sprinkler and basement requirements, see page 374.

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

**OCCUPANCY F-1: INDUSTRIAL, HIGH HAZARD**

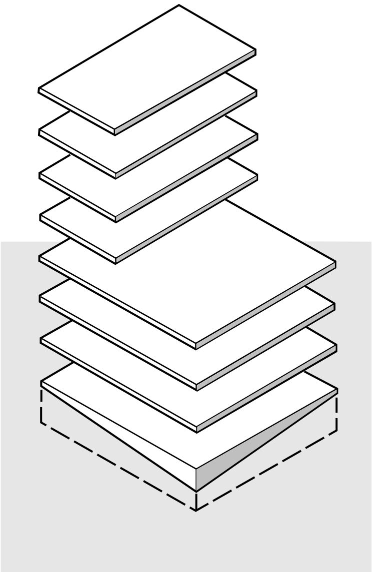
| | | **Noncombustible** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | 2,250 | | | | | | | |
| | 3 | 3,000 | | 1,200 | | 1,200 | | | |
| | 2 | 4,500 | | 1,800 | | 1,800 | | 1,200 | |
| | 1 | 9,000 | 800 | 3,600 | 800 | 3,600 | 800 | 2,400 | 800 |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| **Heavy Timber (page 382)** | | **1-Hour (page 384)** | | **¾-Hour (page 384)** | | **Unprotected (page 384)** | | **CONSTRUCTION TYPE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | |
| | | | | | | | | UH **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| | | | | | | | | 4 |
| 1,200 | | | | | | | | 3 |
| 1,800 | | 1,200 | | 1,200 | | | | 2 |
| 3,600 | 800 | 2,400 | 800 | 2,400 | 800 | 800 | 800 | 1 |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY F-2: INDUSTRIAL, MEDIUM-HAZARD

### Special Requirements

For Small Buildings, see page 371.

For additional sprinkler and basement requirements, see page 374.

### Excess Frontage

For unsprinklered Noncombustible Unprotected Construction buildings, the tabulated areas below may be increased by 25% if the building faces at least two streets and by 50% if it faces at least three streets. For all other unsprinklered buildings, the tabulated building area may be modified for three-story buildings only, such that when the building faces two streets, the building area may be 1340 $m^2$ (14,424 sq ft), and when it faces three streets, the building area may be 1500 $m^2$ (16,146 sq ft).

### Measurements

Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 $m^2$ = 10.76 sq ft

**OCCUPANCY F-2: INDUSTRIAL, MEDIUM HAZARD**

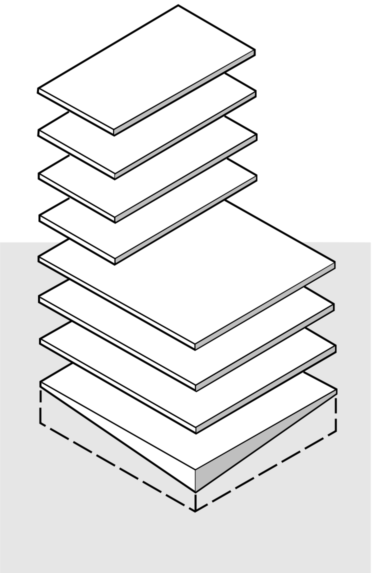
| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | | | | | | | |
| | 6 | | | | | | | | |
| | 5 | | | | | | | | |
| | 4 | | | 4,500 | | 2,400 | | | |
| | 3 | | 1,070 | 6,000 | 1,070 | 3,200 | 1,070 | | |
| | 2 | | 1,500 | 9,000 | 1,500 | 4,800 | 1,500 | 1,800 | 600 |
| | 1 | | 1,500 | 18,000 | 1,500 | 9,600 | 1,500 | 4,500 | 1,000 |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Heavy Timber (page 382)** | | **Wood Light Frame** | | | | | | |
| | | **1-Hour (page 384)** | | **¾-Hour (page 384)** | | **Unprotected (page 384)** | | **CONSTRUCTION TYPE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| 2,400 | | 2,400 | | 2,400 | | | | 4 |
| 3,200 | 1,070 | 3,200 | 1,070 | 3,200 | 1,070 | | | 3 |
| 4,800 | 1,500 | 4,800 | 1,500 | 4,800 | 1,500 | | | 2 |
| 9,600 | 1,500 | 9,600 | 1,500 | 9,600 | 1,500 | NP | NP | 1 |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY F-3: INDUSTRIAL, LOW-HAZARD

### Special Requirements

In addition to the information on height and area limits provided in the table below:

- A single-story unsprinklered building of Unprotected Noncombustible or ¾-Hour Combustible Construction may be 7200 $m^2$ (77,500 sq ft) in area.
- A single-story unsprinklered building of Unprotected Noncombustible or Heavy Timber Construction may be 5600 $m^2$ (60,278 sq ft) in area if the building faces one street, 7000 $m^2$ (75,347 sq ft) if it faces two streets, and 8400 $m^2$ (90,417 sq ft) if it faces three streets.
- A single-story sprinklered building of Unprotected Noncombustible or Heavy Timber Construction may be 16,800 $m^2$ (180,834 sq ft) in area.

See also Small Buildings, page 371.

For additional sprinkler and basement requirements, see page 374.

### Vehicle Parking Garages

For enclosed parking garages, which rely on mechanical ventilation to prevent the accumulation of exhaust gasses, and for naturally ventilated open parking garages with other occupancies above, use the height and area tables on these two facing pages. For open parking garages without other occupancies above, use either the tables on these two facing pages or those on pages 470-471 for Occupancy F-3: Open-Air Garages.

The minimum clear height within parking garage tiers is 2 m (6 feet 7 inches). Every story of a below-grade garage must be sprinklered, except when the story is open-air. For more information on the design of parking facilities, see Designing for Parking, beginning on page 327.

For wall opening and building separation distance requirements for open parking garages, see page 345. For special height and area provisions for mixed-use, below-grade parking with other occupancies above, see page 371. For parking garages serving single dwelling units in small buildings, see page 371.

**OCCUPANCY F-3: INDUSTRIAL, LOW HAZARD**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$** | UH | UA | | | | | | | |
| | 6 | | 2,400 | 7,200 | 2,400 | | | | |
| | 5 | | 2,880 | 8,640 | 2,880 | | | | |
| | 4 | | 3,600 | 10,800 | 3,600 | 3,600 | 1,200 | 3,600 | 1,200 |
| | 3 | | 4,800 | 14,400 | 4,800 | 4,800 | 1,600 | 4,800 | 1,600 |
| | 2 | | 7,200 | 21,600 | 7,200 | 7,200 | 2,400 | 7,200 | 2,400 |
| | 1 | | UA | UA | UA | 14,400 | 4,800 | 14,400* | 4800* |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

[a] See the accompanying text Special Requirements.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |

# NATIONAL BUILDING CODE OF CANADA

## Unlimited Area Buildings

A single-story unsprinklered building of any Noncombustible Construction Type may be of unlimited area, provided that it is used for low-fire-hazard activities, such as power generation or the manufacture and storage of noncombustible materials.

## Excess Frontage

For unsprinklered buildings, the tabulated areas below may be increased by 25% if the building faces at least two streets and by 50% if it faces at least three.

## Measurements

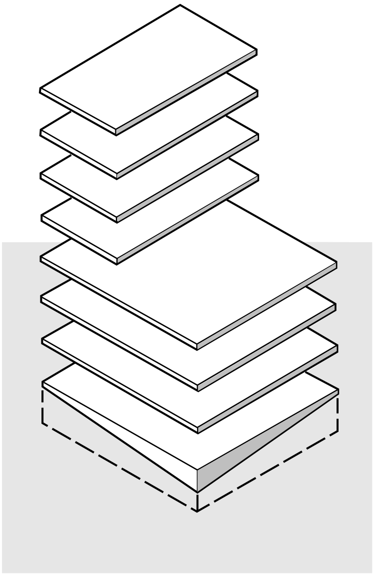
Height is measured as the number of stories at grade or above, excluding the roof. Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

## Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

## Unit Conversions

1 $m^2$ = 10.76 sq ft



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | CONSTRUCTION TYPE |
| Spr | Unspr | Spr | Unspr | Spr | Unspr | Spr | Unspr | HEIGHT IN STORIES ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN $m^2$ |
| | | | | | | | | UH |
| | | | | | | | | 6 |
| | | | | | | | | 5 |
| 3,600 | 1,200 | 3,600 | 1,200 | 3,600 | 1,200 | | | 4 |
| 4,800 | 1,600 | 4,800 | 1,600 | 4,800 | 1,600 | | | 3 |
| 7,200 | 2,400 | 7,200 | 2,400 | 7,200 | 2,400 | | | 2 |
| 14,400[a] | 4800[a] | 14,400 | 4,800 | 14,400 | 4800[a] | NP | NP | 1 |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

## OCCUPANCY F-3: OPEN-AIR GARAGES

### Special Requirements

Garages, as shown in the table below, may not be more than 22 m (72 ft) high, measured from grade to the underside of the top-level ceiling; may have no other occupancy above; and may have no point on any floor that is more than 60 m (197 ft) from an exterior wall opening. For garages that do not meet these criteria, see the height and area requirements for Occupancy F-3, Industrial, Low Hazard, pages 468–469.

For wall opening and building separation distance requirements for open parking garages, see page 345.

The minimum vertical clear height within parking garage tiers is 2 m (6 feet 7 inches). For more information on the design of parking facilities, see Designing for Parking, beginning on page 327.

### Measurements

Area is measured as the greatest horizontal projection of the building above grade within the outside surfaces of exterior walls or the centerline of fire walls.

### Further Information

For information on Occupancy classifications, see page 13. For information on mixed-use buildings, see page 371. For information on which code to consult, see pages 5–6 and 13.

### Unit Conversions

1 m$^2$ = 10.76 sq ft

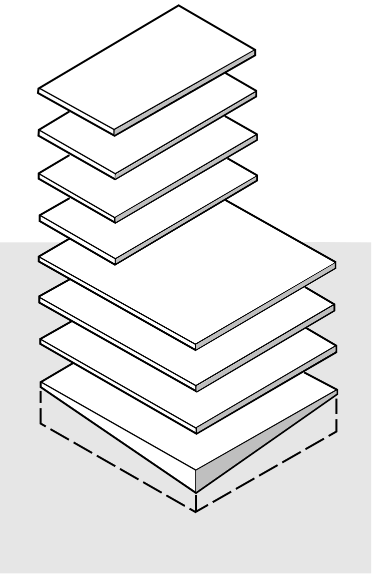
**OCCUPANCY F-3: OPEN AIR GARAGES**

| | | Noncombustible | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CONSTRUCTION TYPE** | | **2-Hour (page 380)** | | **1-Hour (page 381)** | | **¾-Hour (page 381)** | | **Unprotected (page 382)** | |
| | | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** |
| **HEIGHT *IN METERS* ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** | | | | | | | | | |
| | 22m | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| | | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| | | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| | | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| | | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| | | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |

Each number in the table represents the maximum area per floor in square meters for each floor of a building of the indicated story height.

Key to Abbreviations

| | | | |
|---|---|---|---|
| UA | Unlimited area | Spr | With sprinkler system throughout the building |
| UH | Unlimited height | Unspr | Without sprinkler system throughout the building |
| NP | Not permited | | |



| Combustible | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Wood Light Frame | | | | | | |
| Heavy Timber (page 382) | | 1-Hour (page 384) | | ¾-Hour (page 384) | | Unprotected (page 384) | | **CONSTRUCTION TYPE** |
| **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | **Spr** | **Unspr** | |
| NP | NP | NP | NP | NP | NP | NP | NP | 22m **HEIGHT *IN METERS* ABOVE GRADE AND MAXIMUM AREA PER FLOOR IN m²** |

This table was compiled from information contained in the National Building Code of Canada 2010. It does not represent an official interpretation by the organization that issues this code.

# APPENDIX A
# EXAMPLE USE OF THIS BOOK

The following example illustrates the use of this book to complete the preliminary design of a building's technical systems. For a more brief explanation of approaches to using this text, see How to Use This Book, page ix.

## THE PROBLEM

You are beginning the design of a suburban office building on a large site in the Midwestern United States. Preliminary design assumptions are:

- A three-story structure
- A building area of 86,000 sq ft per floor
- Structural column bays 30 × 34 ft, to work well with office furniture system modules
- A floor-to-ceiling height of about 9'-6''
- A fully sprinklered building.

## BUILDING CODE AND OCCUPANCY

We refer first to Designing with Building Codes. On page 5, we determine that our building should be designed to the requirements of the International Building Code. Referring to the Index of Occupancies on page 9, we see that Business Offices are classified as Occupancy B. To learn more about this Occupancy B, Business, we also review its description on page 6 and verify that this is the appropriate choice for our project.

## BUILDING HEIGHT AND AREA LIMITS

Next, we refer to the introductory material on building code height and area limitations beginning on page 366. Reading from the table on that page, we note that requirements for International Building Code Occupancy B buildings can be found on pages 398–399. Turning to these pages, we see that the area figures provided in the table are for all floors of a building. The total area of our proposed building is 258,000 sq ft (86,000 sq ft per floor × 3 floors). Reading from the table, we determine that our building must use at least sprinklered Type II-A 1-Hour Construction.

## CONSTRUCTION TYPE

Following the page references in the height and area table for Type II-A Construction, we turn to page 381 and determine that we can use any of the following construction methods:

- Structural steel with 1 hour of fire protection
- Sitecast concrete or precast concrete, with minimum sizes of components as noted in the text
- Light gauge steel
- Masonry

## SELECTING A STRUCTURAL SYSTEM

We turn to pages 24–35 for advice on selecting a structural system. Light gauge steel and masonry are rejected because of the long spans required for our design. Other factors that seem most important for this project are minimizing erection time during construction and providing concealed spaces for mechanical and electrical services, which will be large and complex in this building. We decide to proceed with structural steel, which satisfies these requirements and tends to be economical in the location where we are building. On page 31, we verify that structural steel can easily span the 30 × 34-ft dimensions assumed for our standard structural bay.

## CONFIGURING THE STRUCTURAL SYSTEM

Reviewing pages 39–47, we determine that our structure should be a column and beam system. Economical options for achieving lateral stability include a shear wall, a braced frame, or a system using semirigid joints in combination with one of the former choices. With these options, we are satisfied that we will be able to include the necessary elements to achieve lateral stability in our structure without difficulty.

## SIZING THE STRUCTURAL SYSTEM

### Columns

The page references at the top of the chart on pages 28–29 direct us to pages 96–104 for information on sizing steel structures. After reviewing the introductory information on page 91, we turn to pages 96–97 for the sizing of structural steel columns. A ground floor column is the most critical, as it supports a total tributary area of two floors plus one roof times the size of a column bay, or 3060 sq ft (three levels × 30 ft × 34 ft).

The normal-height column chart on page 97 indicates that a W8 or W10 column is required. Noting on page 32 that office building structures are subjected to light to medium live loads, we will assume a W8 column for preliminary design purposes and note its dimensions as 8 by 8 in. On upper floors, we will assume that a lighter-weight version of the W8 shape is used. Maintaining the same nominal size will simplify connections between column sections. (Alternatively, our fabricator and erector may opt to use a single piece, three stories high, for each column.)

### Decking

Next, we turn to pages 100–101 for steel floor and roof decking, and determine that decking spans in the range of 6 to 15 ft are most practical. We will return to these pages to determine the final floor slab thickness after we investigate further the framing of beams and girders.

### Bay Framing and Floor Slab

Turning to page 102, we look at a beam and girder framing and note the recommendation to span girders the short direction of the structural bay, or, in our case, in the 30-ft direction. For beam spacing, we consider placing beams at third points along the girder, resulting in a beam spacing of 10 ft. Returning to page 101, we see that this requires us to use 2-in. metal decking with a total slab depth of 4½ to 5 in., including the concrete topping. Reading from the lower chart on the same page, we choose 2-in.-deep roof decking.

Alternatively, we could consider placing beams at girder quarter points, resulting in a beam spacing of 7½ ft. In this case, returning to page 101, we see that we can use 1½ in. metal decking with a total slab depth of about 4 in. Later in the design process, we will ask our structural engineer to consider the economics of both of these options.

### Sizing of Beams and Girders

Next, we turn to pages 102–103 for the sizing of beams and girders. Reading from the chart, we see that beams spanning 34 ft will need to be 18 or 21 in. deep. Alternatively, with composite construction, this depth could perhaps be reduced to about 16 in. We decide on an 18-in.-deep beam. Girders spanning 30 ft need to be 18 to 21 in. deep. We will use a lighter-weight, deeper 21-in. section to facilitate the connection with the 18-in.-deep beams.

## TO SUMMARIZE

- Structural bay: 30 × 34 ft
- Girders: 21-in.-deep, span 30 ft
- Beams: 18 in. deep, span 34 ft, spacing 10 ft
- Decking: 2 in. deep, 5-in.-deep total floor slab
- Columns: 8 × 8 in.

## DAYLIGHTING

We wish to investigate how the use of daylighting may affect the shape of our building. Using the tabs on the page edges, we quickly find the section, Designing with Daylight. On page 143, we determine that our site is open and does not have any significant obstructions to daylight. On page 145, we note that an elongated plan that puts work areas within approximately 30 ft of windows is recommended. This is further explained on page 146. Considering our building, if it were two bays at 30 ft wide each, or 60 ft wide total, it would be 1400 ft long, over a quarter of a mile. Alternatively, we could build to four or five stories, or we could arrange the plan of the building with many branches, as illustrated in the plan diagrams.

On a more detailed level, we note that light shelves could help to control light distribution (pages 151–152), and that we should try to keep window heads as high as possible (page 153). On the uppermost floor, toplighting may be a good option to consider.

In conclusion, we will explore building designs as long and slender as practical in order to place the largest number of workers within daylit distance of outside walls. We will also keep window heads as high as possible. After the building design has progressed further and basic floor plans and sections have been prepared, we will return to this section to carry the daylighting design further.

## MECHANICAL AND ELECTRICAL EQUIPMENT

### HVAC Systems

We turn to page 160 to begin the design of our mechanical and electrical systems. Typical choices of HVAC systems are given on pages 164–165. For office buildings, VAV, VAV induction, multizone, and hydronic convectors are listed as recommended options. We will have plenty of space for ductwork, which rules out the need for VAV induction. A multizone system is too complex for this simple, economical building. Hydronic convectors are an auxiliary system that we may wish to use in conjunction with VAV. We select VAV.

We also turn to pages 217–221 to read about passive heating and cooling systems. Based on the climate conditions in our project location and our decision to adopt a relatively slender, elongated building form, we decide that it might be possible to provide natural ventilation cooling to building occupants during the off-peak spring and fall seasons. We make a note to bring this idea to our first meeting with our mechanical engineer, where it can be explored in greater detail.

Returning to the design of our primary heating and cooling system, we go to pages 168–169, which describe a VAV system and its variants and list the major components of the system for which we must find space. VAV box dimensions are given here, but the sizes of the rest of the components will be found elsewhere in this section.

Can we use a packaged system? Suppose that we want to restrict duct runs to 120 ft for economy of operation. This means that each fan room or packaged unit can service an area 240 ft long (ducts run in two opposite directions). For a building 1400 ft long, we would need six zones, each with its own fan room or packaged unit. Each zone would contain 43,000 sq ft on three floors (258,000 sq ft /six zones). Consulting the sizing chart on page 210, to which we are referred by the note on page 169, we discover that these zones are too large for the largest single-packaged unit.

Proceeding with a fan room solution, we turn to the chart on page 212 to determine the sizes of major components of the air handling system. We assume one fan room per zone, serving all three floors in that zone. We read from this chart that for a floor area of 43,000 sq ft, 50,000 cfm of air is required for cooling. Main supply and return ducts will total about 30 sq ft each. If on each floor two main supply ducts are used, each duct will have to be about 5 sq ft (30 sq ft / three floors / two ducts per floor) in area. At a depth of 18 in., each duct will be about 3½ ft wide. Branch ducts will total about 50 sq ft in area for all three floors.

Reading further down on the same chart, each fan room will occupy about 1500 sq ft of floor area, and will need about 130 sq ft of fresh air louver and about 100 sq ft of exhaust air louver. To minimize the ductwork for these items, we will try to locate fan rooms as close as possible to outside wall locations. Pages 184–185 give additional information on fan rooms and ductwork arrangements.

Returning to the chart on page 210, we determine that each zone requires 130 tons of cooling and a mechanical room for the boiler and chiller 1000 sq ft in area. On page 180 is a more detailed description of this facility. Note the need for a chimney. In addition, 200 sq ft of the roof will be occupied by a cooling tower, as shown and described on page 181.

## PLENUM SPACE AND FLOOR-TO-FLOOR HEIGHT

Assuming that most horizontal distribution of services will be above the ceiling, we need to determine the depth of the plenum. Page 208 tells us that we need 20 in. of plenum height beneath the girders. We have previously determined that the girders will be 21 in. deep and the floor slab and decking 5 in. deep, for a total of 26 in. Adding the depths of structure and plenum, we arrive at a total depth of 46 in., or 3 ft 10 in.

A ceiling height of about 9 ft 6 in. is desired. Adding the 3 ft 10 in. plenum to this, we arrive at a floor-to-floor height of about 13 ft 4 in.

## BUILDING EGRESS AND CIRCULATION

Again starting with the page-edge index marks, we go to pages 265–280 for general definitions and guidance on egress layout.

### Occupant Load

To size the egress components, we need to know the occupant load of the building. This is found using page 299. For a business use, an occupant load of 100 sq ft per occupant is specified. Thus, the egress system on each floor must be designed to accommodate 860 occupants (86,000 sq ft per floor/100 sq ft per occupant).

### Egress System

On page 272, we find that we must provide a minimum of three exits from each floor. If the building is 1400 ft long, three exits will give a maximum travel distance of 350 ft. On page 300, we see that the maximum distance to the nearest exit is 300 ft in a sprinklered Business Occupancy building. Therefore, we must provide at least four exits. We decide that for convenience and safety, we will provide six exits.

With six exits, the occupant load per exit is 143 (860 occupants per floor/six exits per floor). Referring to page 302, we see that we must provide 0.2 in. of width per occupant for doors, corridors, and ramps and 0.3 in. per occupant for stairs. We can either work this out arithmetically or use the chart on page 303. For example, for exit stairs, the required width based on the number of occupants is 43 in. (143 occupants × 0.3 in. per occupant). But page 301 tells us that the stair may not be less than 44 in. when serving more than 50 occupants. We will use 44-in. stairs.

### Exit Stairway Design

Now we can determine how big each stair tower is. We go to the Two-Flight Exit Stairway Design table on page 318. Earlier, we calculated our floor-to-floor height to be 11 ft 4 in. The table tells us that we will have 20 risers at 6.80 in., with treads at 11 in. The inside length of the stairway will be 15 ft 7 in. The width will be twice 44 in. plus a center space or wall if we wish it; we assume a 6-in. center wall to arrive at a width of 94 in., or 7 ft 10 in. If we assume 8-in. walls around the stair, the outside dimensions of the stairway will be 16 ft 11 in. by 9 ft 2 in.

### Elevators

Page 201 tells us that we need one elevator for every 35,000 sq ft served. Our building has 258,000 sq ft of floor area, but the ground floor does not need to be considered as a served floor. So the served area is 172,000 sq ft (⅔ × 258,000 sq ft). Dividing 172,000 sq ft by 35,000 sq ft yields 4.9, which we round up to five elevators required. We may want to distribute these in banks of two elevators each to minimize waiting times, which would require six elevators as a minimum.

If we use 3000-lb elevators, we see from the table on the same page that each shaft must have at least 8 ft 4 in. by 7 ft 5 in. inside clear dimensions. If we add to this shaft walls 4 in. thick, the overall shaft dimensions are 9 ft 0 in. by 8 ft 1 in.

As a possible energy-saving strategy, we decide to propose a machine room-less elevator system to our client, as explained on page 203. Further advice on elevators and elevator lobbies is offered on the following pages.

### Accessible Routes

Information on accessibility is provided on pages 281–285. We note that accessibility requirements do apply to our building and that at least 60% of its entrances must be accessible. Accessible egress will be provided by elevators and stairways. As our design develops, we will also be sure to meet the requirements for minimum widths of accessible routes, latchside door clearances, and so on.

## ANCILLARY SPACES

### Transformers and Switchgear Rooms

We will need one or more large transformers to reduce high transmission voltages to lower voltages for use in our building. Pages 182–183 indicate that these may be either mounted on concrete pads at ground level or placed in transformer vaults underground. The sizes required for underground vaults are large, and we realize that pad mounting will be more economical. The largest floor area listed per transformer pad is 180,000 sq ft, which can serve more than half of the floor area of our building. We will look for good locations for at least two transformer pads just outside the walls of the building.

The diagrams on page 189 indicate that each pad will require a switchgear room. If we use two transformers and switchgear rooms, each will serve 129,000 sq ft. The accompanying table shows that a 100,000-sq-ft building needs a room 30 by 20 ft in plan dimension by 11 ft tall. We may need a room somewhat larger than this, say 30 by 30 ft. As noted in the text on this page, each switchgear room should be on an outside wall to facilitate ventilation.

### Electrical and Telecommunications Closets

Electrical closets are described on page 193; no point on any floor should be more than 100 to 125 ft from a closet with internal dimensions of approximately 8 × 10 ft. Additionally, telecommunication closets, with internal dimensions of 10 × 12 ft, should be located such that all points on a floor are not more than 300 ft from such a closet. Both types of closets should be aligned above one another on the three floors. As we begin to develop the floor plans, we will keep these requirements in mind. Given the rapid changes in telecommunications services, we also make a note to review these assumptions at an early date with technical personnel who are familiar with the industry.

### Toilets

Toilet facilities may be sized and planned with the information provided on pages 195–197.

## PARKING

If provision for parking is required, information on the preliminary design of parking facilities can be found beginning on page 331.

## WHERE THIS BRINGS US

In an hour or two, with this book as our consultant, we have made preliminary decisions in every technical area that impacts the configuration of the building we are about to design:

- We have selected a structural system and assigned approximate sizes to its members.
- We are aware of the requirements for daylighting the building.
- We have made a tentative choice of an HVAC system and know the sizes and locations of its major components.
- We know the requirements for egress from the building, including the sizes of the stair enclosures.
- We know the number and size of elevators and have determined requirements for accessibility.
- We have determined the floor-to-floor height and the depth of the ceiling plenum space.
- We know the required components of the electrical and telecommunications systems, their locations, and their sizes.
- We have sized the toilet facilities and, if needed, allocated space for parking.

Thus, we are ready to launch the process of finding a good form for the building, knowing that we will make adequate provisions for all of its major systems.

# APPENDIX B
# UNITS OF CONVERSION

| Inch-Pound (U.S. Customary Units) | METRIC (SI) | METRIC (SI) | Inch-Pound (U.S. Customary Units) |
|---|---|---|---|
| 1 in. | 25.4 mm | 1 mm | 0.0394 in. |
| 1 ft | 304.8 mm | 1 m | 39.37 in. |
| 1 ft | 0.3048 m | 1 m | 3.281 ft |
| 1 lb | 0.4536 kg | 1 kg | 2.205 lb |
| 1 $ft^2$ | 0.0929 $m^2$ | 1 $m^2$ | 10.76 $ft^2$ |
| 1 psi | 6.895 kPa | 1 kPa | 0.145 psi |
| 1 $lb/ft^2$ | 47.88 Pa | 1 Pa | 0.02089 $lb/ft^2$ |
| 1 $lb/ft^3$ | 16.02 $kg/m^3$ | 1 $kg/m^3$ | 0.6243 $lb/ft^3$ |
| 1 ft/sec | 0.3048 m/sec | 1 m/sec | 3.281ft/sec |
| 1 ft/min | 0.00508 m/sec | 1 m/sec | 196.9 ft/min |
| 1 cfm | 0.4719 l/sec | 1 l/sec | 2.119 cfm |
| 1 cfm | 0.0004719 $m^3$/sec | 1 $m^3$/sec | 2119 cfm |
| 1 BTU | 1.055 kJ | 1 kJ | 0.9479 BTU |
| 1 BTU | 0.2521 kcal | 1 kcal | 3.966 BTU |
| 1 BTU/h (BTUH) | 0.2931 W | 1 W | 3.412 BTU/h (BTUH) |

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## DESIGNING WITH HEIGHT AND AREA LIMITATIONS

See Designing with the Building Codes above.

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